Nature-based Solutions in Bangladesh: Evidence of Effectiveness for Addressing Climate Change and Other Sustainable Development Goals

A. C. Smith[1,2]*, T. Tasnim[3], H. Md. Irfanullah[4], B. Turner[2,5], A. Chausson[2] and N. Seddon[2]

[1]Environmental Change Institute, School of Geography and the Environment, University of Oxford, Oxford, United Kingdom, [2]Nature-based Solutions Initiative, Department of Zoology, University of Oxford, Oxford, United Kingdom, [3]International Centre for Climate Change and Development (ICCCAD), Dhaka, Bangladesh, [4]Center for Sustainable Development, University of Liberal Arts Bangladesh, Dhaka, Bangladesh, [5]Centre D'Étude de La Forêt, Département Des Sciences Biologiques, Université Du Québec à Montréal, Montréal, QC, Canada

Many lower-income countries are highly vulnerable to the impacts of natural disasters and climate change, due to their geographical location and high levels of poverty. In response, they are developing climate action plans that also support their sustainable development goals, but conventional adaptation approaches such as hard flood defenses can be expensive and unsustainable. Nature-based solutions (NbS) could provide cost-effective options to address these challenges but policymakers lack evidence on their effectiveness. To address this knowledge gap, we focused on Bangladesh, which is exceptionally vulnerable to cyclones, relative sea-level rise, saline intrusion, floods, landslides, heat waves and droughts, exacerbated by environmental degradation. NbS have been implemented in Bangladesh, but there is no synthesis of the outcomes in a form accessible to policymakers. We therefore conducted a systematic review on the effectiveness of NbS for addressing climate and natural hazards, and the outcomes for other sustainable development goals. Research encompasses protection, restoration and participatory management of mangroves, terrestrial forests and wetlands, as well as conservation agriculture and agro-forestry, but there is an evidence gap for urban green infrastructure. There is robust evidence that, if well-designed, these NbS can be effective in reducing exposure to natural disasters, adapting to climate change and reducing greenhouse gas emissions while empowering marginalized groups, reducing poverty, supporting local economies and enhancing biodiversity. However, we found short-term trade-offs with local needs, e.g. through over-harvesting and conversion of ecosystems to aquaculture or agriculture. To maximize NbS benefits while managing trade-offs, we identified four enabling factors: support for NbS in government policies; participatory delivery involving all stakeholders; strong and transparent governance; and provision of secure finance and land tenure, in line with international guidelines. More systematic monitoring of NbS project outcomes is also needed. Bangladesh has an opportunity to lead the way in showing how high quality NbS can be deployed at landscape scale to

tackle sustainable development challenges in low to middle income countries, supporting a Green Economic Recovery. Our evidence base highlights the value of protecting irreplaceable natural assets such as mangroves, terrestrial forests and wetlands, and the non-market benefits they deliver, in national planning policies.

INTRODUCTION

Many lower-income countries are highly vulnerable to natural disasters and climate change (Chen et al., 2015; Eckstein et al., 2019). As well as being in geologically and/or hydrodynamically unstable areas, and subject to extreme weather, their adaptation options are often limited by low financial, manufactured and human capital, the latter due to low levels of education and healthcare (Moser and Ekstrom, 2010; Spires et al., 2014; Shi et al., 2016). In response, many are developing National Adaptation Plans and Nationally Appropriate Mitigation Actions that seek to adapt to climate change, reduce disaster risk and cut greenhouse gas (GHG) emissions whilst also supporting the delivery of other sustainable development goals (SDGs). Yet commonly adopted adaptation and development approaches such as hard flood defenses (Narayan et al., 2016; Reguero et al., 2018; Ware et al., 2020) and intensive agriculture (Rasul and Thapa, 2004; Prabhakar, 2021) can be expensive and unsustainable. These interventions are static, so that they can become obsolete as climate threats intensify, and often tackle one problem whilst making others worse, for example by increasing GHG emissions and polluting water supplies (Rasul and Thapa, 2004; Prabhakar, 2021). Nature-based solutions (NbS) offer a more holistic approach to societal challenges, by working with and enhancing the natural, human and social capital that underpins long-term human wellbeing. NbS, either alone or combined with other approaches, could thus contribute to cost-effective options for addressing climate change, natural hazards and development challenges while also reversing biodiversity loss (Seddon et al., 2020). However, integration of NbS into national policies is limited (Seddon et al., 2019), partly because policy-makers lack accessible information on their effectiveness for delivering these benefits. The evidence that exists is dispersed across academic papers in journals from the physical, natural and social sciences (Chausson et al., 2020; Seddon et al., 2020), often behind paywalls, or buried in 'grey literature' reports scattered across many different websites. This presents a barrier to policymakers with limited time and resources.

To address this, we have compiled a comprehensive and accessible synthesis of evidence on the effectiveness of NbS for addressing climate change in Bangladesh, one of the most vulnerable countries in the world to the impacts of natural and climate disasters, which are compounded by environmental degradation and socio-economic challenges (Shi et al., 2016). Cyclones, which are becoming more intense due to climate change (Kossin et al., 2020), cause wind damage, coastal flooding and erosion, and together with sea level rise this

contributes to more extensive storm surges (Hoque et al., 2019). The resulting inundation leads to salinization of soil and groundwater that destroys agricultural livelihoods (Wicke et al., 2013; Imam et al., 2016), while saline intrusions are also exacerbated by over-extraction of groundwater for irrigation (Zahid et al., 2018). In hilly areas such as the Chittagong region, the combined effects of forest degradation, hill cutting for housing construction and severe rainfall events cause soil erosion and landslides (Islam and Rahman, 2019), which can be triggered by earthquakes. Climate change is also leading to more severe heat waves and droughts (Imam et al., 2016), while vulnerability to water scarcity is worsened by high levels of water pollution, including widespread pollution of groundwater by arsenic (Akhter and Uddin, 2010). Poverty is widespread, increasing vulnerability to these effects (Shi et al., 2016), and the COVID-19 pandemic is likely to severely affect progress on sustainable development and biodiversity conservation.

This exceptionally high vulnerability to climate change has led to a focus on climate adaptation, but the government of Bangladesh has also committed to a greenhouse gas (GHG) reduction of 21.85% below business-as-usual by 2030, of which 15% is conditional on international support (MoEFCC, 2021). Bangladesh also has an ambition to become an upper middle-income country over the next decade, and the updated Nationally Determined Contribution (NDC) states that the GHG goals should not undermine the national principles of maintaining minimum 8% GDP growth, eradicating poverty by 2030, and ensuring food and nutrition security for all citizens. Bangladesh's NDC further aims at a long-term vision for synergies between adaptation and mitigation actions (MoEFCC, 2021).

Bangladesh has several key natural assets, including two thirds of the Sundarbans (the largest remaining area of mangroves in the world), the Chittagong hill forests in the east, and the unique seasonal wetlands (Haors) in the north-east, but 60% of the country is cropland (FAOSTAT, 2018). Both natural and managed ecosystems are being degraded due to climate change, pollution and over-exploitation of resources, posing an increasing threat to livelihoods, especially for the rural poor (Rasul and Thapa, 2004; Miah et al., 2010; Abdullah-Al-Mamun et al., 2017). NbS offer the potential to reverse this degradation and boost climate resilience, whilst empowering local communities and enabling sustainable development, but they are not well integrated into national policies (Islam et al., 2021), partly due to lack of awareness of their benefits (Huq et al., 2017).

This review aims to 1) identify robust evidence on the effectiveness of NbS in Bangladesh for addressing climate

change, natural hazards and other sustainable development goals; and 2) assess the enabling factors that can accelerate and expand the uptake of good quality NbS. We build on the methodology of two recent assessments: a global systematic map of evidence on the effectiveness of nature-based interventions for adapting to the impacts of climate change (Chausson et al., 2020) and a review of the outcomes of NbS on development in lower-income countries (Roe et al., 2021). We expanded the scope of these global reviews to carry out a deeper analysis and synthesis for one country. This evidence highlights the benefits provided by NbS, and their potential to help developing countries reach their economic and environmental goals.

METHODS

Systematic Review Protocol
Target Interventions
NbS are defined as actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits (Cohen-Shacham et al., 2019; Seddon et al., 2021). For example, protecting and restoring forests can help to reduce the impacts of floods and landslides, while nature-based agricultural techniques such as the use of leguminous cover crops can improve the water-holding capacity of the soil, helping to combat droughts. We include modelling studies that assess the potential benefits of NbS that have not yet been implemented, and, similarly, we include assessments of the benefits delivered by existing ecosystems, because this evidence is a useful proxy for the benefits that would be delivered through protecting, restoring, or managing the ecosystems through future NbS actions. We use this approach because our aim is to gather evidence on the potential future effectiveness of scaling up the deployment of NbS in Bangladesh, not only on the benefits currently being delivered by NbS that are already implemented.

NbS should be designed and implemented with the full engagement and consent of Indigenous Peoples and local communities, and must sustainably provide one or more benefits for people whilst causing no loss of biodiversity or ecological integrity (or preferably a gain) compared to the pre-intervention state (Seddon et al., 2021). It was rarely possible to determine whether all these criteria were met based on the information given in the papers, hence some interventions may not qualify as 'solutions', as per the NbSI guidelines and the IUCN standard (NbSI, 2020; IUCN, 2020). However, we recorded any relevant information on biodiversity and social impacts, even where it seemed possible that mixed or negative impacts might have occurred, because this is important in highlighting lessons for NbS design in future. We considered the likely baseline or counterfactual scenario, i.e. what would have happened in the absence of the intervention. We therefore included interventions such as agro-ecological farming methods if the most likely alternative was a continuation of more damaging practices, and sustainable fishery management if the alternative was a continuation of over-harvesting. We use the term biodiversity in its broadest sense, with a positive

outcome for biodiversity indicating a move towards an appropriate mix and abundance of habitats and species for each location, acknowledging that some ecologically valuable habitats have naturally low species diversity.

Target Outcomes
The strength of NbS is that they can simultaneously address multiple challenges. Outcomes can arise either from changes to ecosystems to support or increase the provision of ecosystem services or through the process of implementing the NbS, such as through training, employment, and empowerment. In this way, NbS can address climate and natural hazards at the same time as contributing to other sustainable development goals. They can reduce vulnerability to climate change and natural hazards by reducing exposure to impacts (e.g., forests protecting against floods), reducing sensitivity to impacts (e.g., by diversifying livelihood options) and increasing the capacity to adapt to change (e.g., by empowering communities and individuals) (Thiault et al., 2021). In addition, GHG mitigation reduces hazards by limiting the magnitude of climate impacts, and biodiversity underpins the adaptive capacity and healthy functioning of the ecosystem, for example by maintaining genetic diversity that could confer resilience to future pests and disease. We drew up a list of relevant NbS outcomes adapted from Roe et al. (2021), and identified how they address climate and natural hazards and contribute to the SDGs (**Table 1**). These are hereafter referred to as the 'target outcomes' for the review. Further details are provided in the **Supplementary Information**.

The systematic review was based on the methodology of Chausson et al. (2020), which used the scoping elements listed in the top row of **Table 2**. In order to restrict their global search to a manageable number of articles, Chausson et al. (2020) searched academic articles only, and excluded the categories shown in the middle row of **Table 2**. These criteria retrieved only two papers for Bangladesh. For this in-depth country-level study we removed all these exclusion criteria, as shown in the bottom row of **Table 2**, and we also searched for evidence from books, conference proceedings and grey literature.

Search and Screening Process
Academic Literature
The search string (see **Supplementary Information**) included recognized intervention terms (e.g., nature-based solution, ecosystem-based adaptation, agroforestry), the people or sector benefiting from NbS (e.g., local communities, policymakers, food systems), the challenge targeted (e.g., climate change, flood, drought, landslide) and the outcome (e.g., food security, adaptation, mitigation, protection, resilience). The string was based on that used by Chausson et al. (2020) but after review by the co-authors based in Bangladesh we included one additional local term ("floating gardens"). We also added an extra step in which we simply searched for "Nature-based solutions" (and related terms) and "Bangladesh". This was to check that we had not inadvertently screened out any relevant studies due to the complex and specific search terms used for the main search. We searched only for studies of NbS in Bangladesh.

TABLE 1 | Target outcomes from NbS for addressing climate change and other SDGs, either through ecosystem change or through the NbS implementation process.

Broad category of outcome	Outcomes from the NbS	Addresses				Through	
		Exposure	Sensitivity	Adaptive capacity	SDGs[a]	Ecosystem	NbS implementation
Climate change mitigation	GHG concentrations	x			13	x	
Inland flooding and erosion	Inland flooding	x			13	x	
	Soil erosion	x			2, 13	x	
	Mudslides/landslides/avalanche	x			13	x	
Coastal flooding, erosion and salinization	Coastal flooding	x			13	x	
	Coastal erosion	x			13	x	
	Coastal saltwater intrusion (groundwater)	x			13	x	
	Salinization (surface)	x			2, 13	x	
Wind damage	Wind and storm damage (other than flooding)	x			13	x	
Heatwaves	Heatwaves	x			3, 11, 13	x	
Wildfire	Wildfire	x			13	x	
Desertification	Desertification	x			13	x	
Water security	Drought/reduced rainfall	x			2, 6, 13	x	
	Water quantity/availability	x			6	x	
	Surface water quality	x			6	x	
	Groundwater quality	x			6	x	
Food security	Food production/security/nutrition		x		1, 2	x	
	Fishing		x		1, 2	x	
	Aquaculture		x		1, 2, 12	x	
	Soil quality		x		2	x	
	Pests		x		2	x	
Wood, fuel and NTFP (Non-timber forest products)	Wood production (forestry)		x		1, 12	x	
	Fuelwood supply		x		1	x	
	Biofuel production		x		1	x	
	Other ecosystem goods (e.g. NTFP)		x		1, 12	x	
Air quality	Air quality	x	x		3	x	
Disease risk	Disease incidence and distribution	x	x		3	x	
Cultural outcomes	Aesthetic value		x		3	x	
	Recreation (local)		x		3	x	
	Cultural heritage, spiritual values and inspiration		x	x	3	x	x
Socio-economic outcomes	Tourism		x		1, 3, 8	x	x
	Employment		x		1, 8	x	x
	Local economic benefits		x		1, 8	x	x
	Education and training		x	x	1, 4	x	x
	Rights, empowerment and inequality (incl. gender)		x	x	5, 10	x	x
	Social cohesion, governance and engagement		x	x	16, 17		x
Ecological outcomes	Biodiversity and ecosystem health			x	14, 15	x	

[a]SDGs: 1 No poverty, 2 Zero hunger, 3 Good health and well-being, 4 Quality education, 5 Gender equality, 6 Clean water and sanitation, 7 Affordable and clean energy, 8 Decent work and economic growth, 9 Industry, innovation and infrastructure, 10 Reduced inequalities, 11 Sustainable cities and communities, 12 Responsible consumption and production, 13 Climate action, 14 Life under water, 15 Life on land, 16 Peace, justice and strong institutions, 17 Partnership for the goals.

We searched Web of Science and Scopus on May 7, 2020 for articles, reviews, conference proceedings, reports or book chapters that matched these terms. We excluded duplicates using EndNote, and screened first titles and then abstracts to eliminate sources that clearly did not contain any evidence of NbS effectiveness for delivering the target outcomes. As the aim of this review was to conduct an in-depth analysis of the strongest evidence, we then performed a further screening round, selecting only the sources that explicitly referred to evidence on the effectiveness of NbS for delivering the target outcomes in the abstract. The sources excluded at this stage included many general texts or reviews about climate change adaptation or mitigation, some of which did not explicitly refer to NbS in the abstract, most of which appeared to consist largely of secondary information taken from other studies. However, it is possible that some of these sources may contain some primary evidence on NbS effectiveness. Finally, some additional studies were excluded at the full-text screening stage, either because they were duplicate studies or because they were not relevant.

Grey Literature

Many NbS projects in Bangladesh are not included in peer-reviewed journals. It was therefore important to analyze grey literature on

TABLE 2 | Framing of the search criteria for the systematic review: differences to the global review by Chausson, Turner et al. (2020).

Subject/Population	Intervention	Comparators	Outcomes
Chausson, Turner et al. (2020) criteria			
Human individuals, groups, communities and economic sectors (e.g., agriculture, water, forestry, transport, energy)	Actions in rural, semi-rural or peri-urban settings involving management, restoration or protection of biodiversity, ecosystems, or ecosystem services, or involving the creation or management of artificial ecosystems (excluding agriculture, fisheries and aquaculture)	Pre-intervention baselines or repeat assessments over time; quasi or experimental controls (no adaptation action); modeled counterfactuals, or evaluator inference of a counterfactual (i.e. what would have happened in the absence of the intervention)	Measured, observed, or ex-ante modeled outcomes (regulating or provisioning ecosystem services) addressing the impacts of weather hazards or climate change on people or economic sectors
Exclusions in Chausson, Turner et al. (2020)			
1. Effects of nature-based interventions on impacts not explicitly reported as being driven (at least in part) by climate or hydro-meteorological phenomena 2. Effects on vulnerability (including social adaptive capacity) only arising from the implementation, management or governance of the nature-based intervention, rather than (at least in part) from the flow of ecosystem services 3. Urban nature-based solutions, hybrid natural/engineered interventions, agricultural interventions (such as agroforestry), rangeland, or fisheries interventions not involving ecosystem restoration or protection 4. Effectiveness of existing ecosystems for adaptation relevant services, unless an intervention (e.g. protection or restoration) was involved			
Modifications to criteria for Bangladesh review			
Same	Urban NbS, hybrid NbS, agriculture, fisheries and aquaculture included Effectiveness of existing ecosystems was included even in the absence of an explicit intervention	Same	Included all the outcomes in **Table 1**

these interventions. Because non-academic search engines return very large numbers of hits, most of which are not relevant, we used the knowledge of local experts and networks to narrow down the search to the most relevant resources. From our personal knowledge and experience of the implementation of NbS in Bangladesh, together with discussion with members of the 'NbS Bangladesh Network', a community of researchers, practitioners and policymakers (www.nbsbangladesh.info), we identified four major projects implemented in Bangladesh over the past 22 years. These projects focused on community-based natural resource management, ecosystem-based adaptation and biodiversity conservation, and covered multiple sites in the Sundarbans, the coast, the Chittagong Hills and the Haor wetlands. We searched for reports from these projects through online sources and personal contacts, and finally selected three final reports (one in two volumes) (DoE, 2015; IUCN Bangladesh, 2016; MACH-II, 2007a; MACH-II, 2007b) and one performance report (Winrock International, 2018). From these we identified 24 interventions that qualify as NbS.

Many other projects followed ecosystem-based approaches in Bangladesh, but documents with adequate evidence were not available. This reflects challenges with the grey literature evidence base. Documents often state outcomes (mainly in qualitative terms) without fully describing the methodology used to determine the outcome, so it is not possible to assess the robustness of the information, and often they do not follow a consistent impact assessment methodology throughout the whole project period.

Coding Strategy

For each paper or report reviewed, we extracted data on the NbS interventions and their outcomes into a spreadsheet, based on a coding template adapted from Roe et al. (2021) (see **Supplementary Information**). For each NbS intervention we recorded the location, NbS type (protection, restoration, management or creation of ecosystems, or nature-based food production), ecosystems involved, funders, instigators, partners, beneficiaries, economic costs of implementation, and synergies and trade-offs between outcomes. We also collected information on 'enabling factors' reported to influence the successful implementation and governance of the NbS, including the role of institutions, the involvement of local communities, and the use of local knowledge.

For each outcome of an intervention, we recorded the type of outcome (**Table 1**), direction of outcome (positive, negative, mixed, unclear), the attributes of the ecosystem that influenced the outcome (e.g., species richness; presence of particular species); the methods used to determine the outcome, and the quality of the evidence. All financial amounts are presented as they appeared in the corresponding literature. In 2021, US\$ 1 was equivalent to approximately Bangladesh Taka 85.

We assessed the quality of the evidence using the protocol in the **Supplementary Information (Section S3.17)**. We recorded whether there was any conflict of interest declared, or if the authors were also involved in implementation of the study, although these papers were not excluded. For each outcome reported, we then recorded whether primary evidence was used and displayed, or secondary evidence provided with references; whether the methodology was clear and appropriate; whether results were reported with respect to a counterfactual or baseline (if appropriate); and whether confounding factors were taken into account. Outcomes that met all these criteria were deemed to have robust evidence.

We also recorded any examples mentioned in each study of 'enabling factors' that enabled the successful deployment of NbS.

Analysis and Synthesis of Results

We produced descriptive statistics of the results, including the number of interventions studied in different ecosystems, and the number of positive, negative, mixed or unclear outcomes for each type of intervention (*Number of Studies and Quality of the Evidence Base* and *Type of Nature-based Solutions Interventions*). We then synthesized evidence on the effectiveness of NbS interventions for addressing climate change, natural hazards and other sustainable development goals, described in narrative form with supporting examples in a table (*Effectiveness of Nature-based Solutions for Addressing the Target Outcomes*). Finally, we synthesized information on enabling factors for scaling up high quality NbS and presented this in narrative form (*Enabling Factors for Successful Implementation of Nature-based Solutions*).

RESULTS

Number of Studies and Quality of the Evidence Base

The search of academic literature retrieved 1,173 non-duplicate articles of which 56 remained for coding after all the screening stages (**Supplementary Figure S1**, **Supplementary Table S1**). Five papers that contained no outcome evidence did contain useful material on enabling factors; These were coded in the spreadsheet.

These 56 papers reported 154 outcomes, of which 96 (62%) had robust evidence, i.e., they reported and displayed primary data, they used a clear and appropriate methodology, used a counterfactual or baseline (if applicable), and they attempted to account for confounding factors (if applicable). Of the outcomes, 115 were based on quantitative data (75%), and 46 (30%) reported qualitative data, with seven of these (5%) using both. Sixteen of the outcomes were based on experiments, 14 on modelling, 77 on interviews and 34 on *in-situ* observations, of which 16 also used interviews. Six outcomes were based on literature reviews, and one was based only on anecdotal evidence. For 88 outcomes across 21 academic studies, participatory approaches were used, including through interviews and focus groups. This included approaches incorporating traditional or indigenous knowledge, including knowledge of local farming techniques, crop cultivars, crop pests, cultural values and use of forest products.

None of the 85 outcomes reported in the grey literature were based on robust evidence. Also, as the authors were involved in the interventions, the reports cannot be considered as independent evaluations. Only 36% of the outcomes were reported as quantitative evidence (of which 21% also provided qualitative evidence), and this often concerned intermediate outputs (e.g., the area of habitats restored, the number of community organizations established or the number of training courses provided) rather than final outcomes. Most of

**FIGURE 1 |** Type of NbS intervention included in the studies that were reviewed.
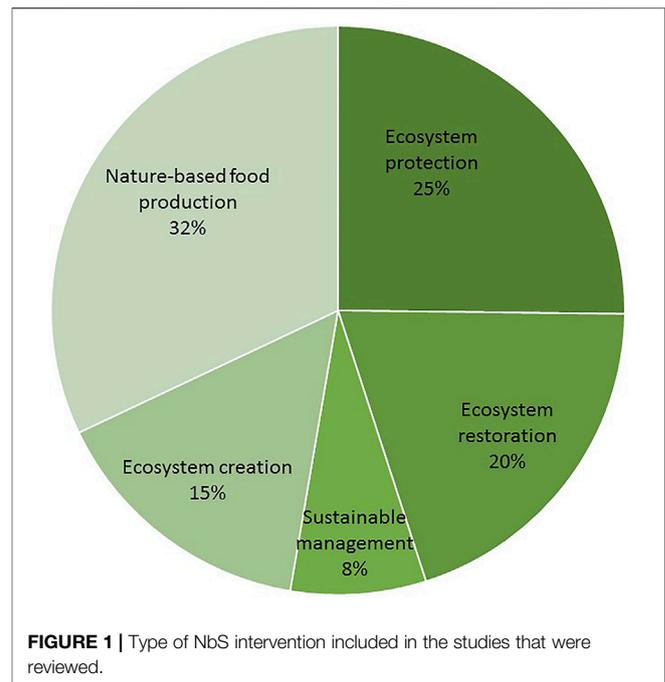
the outcomes (64%) were based only on qualitative evidence, sometimes from interviews and surveys of community perceptions of benefits, but often it was not clear how the evidence was obtained. Biophysical outcomes such as flood and erosion prevention were often reported as inferred or expected outcomes resulting from an intervention (e.g., 'vegetation was planted to provide protection from flooding and erosion'), and thus could not be included in the evidence base. The lack of quantitative data also limited the scope for economic analysis of costs or benefits. However, the reports often provided rich detail of real-life governance, engagement and capacity building challenges and lessons on how these could be addressed.

Type of Nature-based Solutions Interventions

The most frequent type of intervention in the literature reviewed was nature-based food production (32%), followed by protection and then restoration of ecosystems (**Figure 1**). Although only 8% of interventions are classified as solely 'ecosystem management', many of the nature-based food production studies also involved management (e.g., of cropland or fisheries).

The most common ecosystem involved in the NbS interventions was cropland, followed by inland wetlands, agroforestry, mangroves, tropical forests, and plantations, with just a few studies of NbS in other habitats (**Figure 2**). There was a notable gap for urban green and blue infrastructure, with only one study, focusing mainly on the role of roof gardens for food production (Zinia and McShane, 2018). From the combination of the type of intervention (protection, restoration etc.), the ecosystem involved, and terms used to describe certain types of intervention (e.g., "conservation agriculture") we generated a

FIGURE 2 | Number of interventions reviewed for each ecosystem type.
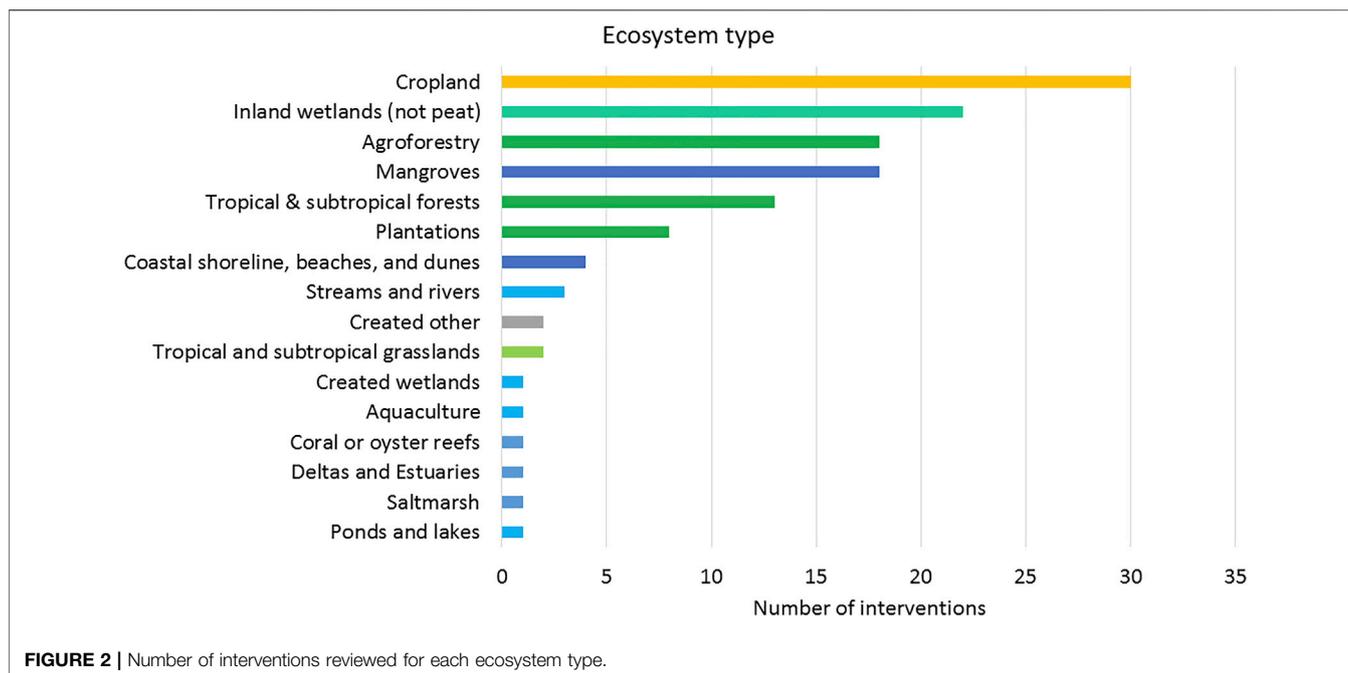
list of the main types of interventions identified in the review (**Table 3**).

Effectiveness of Nature-based Solutions for Addressing the Target Outcomes

The review identified evidence on the capacity of NbS to address all the target outcomes except wildfires, desertification, and the spread of diseases, for which no evidence was found. The most frequently recorded outcomes were for food production, climate change mitigation, biodiversity, fishing, and coastal flooding (**Figure 3**). Most (91%) were positive, with only 3% being negative and 2% mixed (the rest were neutral or unclear).

We summarized the positive links between different NbS interventions (**Table 2**) and target outcomes (**Table 1**) in **Table 4**. The most frequently reported evidence was for the coastal protection and socio-economic benefits of mangroves (15 positive outcomes each), followed by the benefits of conservation agriculture for food security (13 positive outcomes). These were also the most frequently reported outcomes when looking only at robust evidence (**Supplementary Table S6**).

From the information reported in the studies, we recorded which attributes of the ecosystem positively influenced the outcomes. Out of the 228 outcomes reported, 96 depended on the presence of a specific habitat or ecosystem, 61 were influenced by species abundance, 57 required the presence of a specific functional group such as trees, fish or birds, 44 were influenced by species richness or diversity (including 24 biodiversity outcomes), 18 by soil carbon or soil health and one (slope stabilization) by root morphology (Islam and Rahman, 2019), with some overlaps, i.e., some outcomes were influenced by more than one ecosystem attribute.

In the following sections we synthesize the evidence on the effectiveness of NbS for addressing each of the target outcome groups in Bangladesh, and show how these are linked to the Sustainable Development Goals. For clarity, details and citations for many of the examples used in this section are presented in **Table 5**.

Greenhouse Gas Reduction

There were 22 records of positive outcomes for GHG reduction and one mixed outcome. Sixteen were from forests and six from conservation agriculture.

Protecting and restoring mangrove forests is particularly important as they trap carbon-rich sediment amongst their roots, as well as storing carbon in biomass. Carbon storage was estimated at 219 tC/ha (Rahman et al., 2017) to 257 tC/ha, of which 63% was belowground in the soil and roots (Abdullah-Al-Mamun et al., 2017). However, the global average for oceanic mangroves was estimated as 400 tC/ha, suggesting that mangroves in Bangladesh could be relatively degraded (Chow, 2018). Mangroves were estimated to sequester carbon four times faster than mature land-based forests, offsetting 1.5% of Bangladesh's fossil fuel carbon emissions in 2014 or 10% from 1997 according to different estimates (**Table 5**). Conversion to aquaculture was highlighted as a threat, as it requires excavating at least 2 m of sediment, which can release 70 tC/ha of carbon (Chow, 2018).

We found fewer studies on carbon storage and sequestration in **native terrestrial forests**, which include the mixed evergreen forests in the Chittagong Hill Tracts and the much smaller fragments of deciduous Sal forests (*Shorea robusta*) in central Bangladesh. Progress towards protecting and restoring forests for carbon benefits via REDD+ faces governance challenges in Bangladesh, especially in the Chittagong Hill Tracts (Richards

TABLE 3 | Main types of NbS intervention identified in the review for Bangladesh.
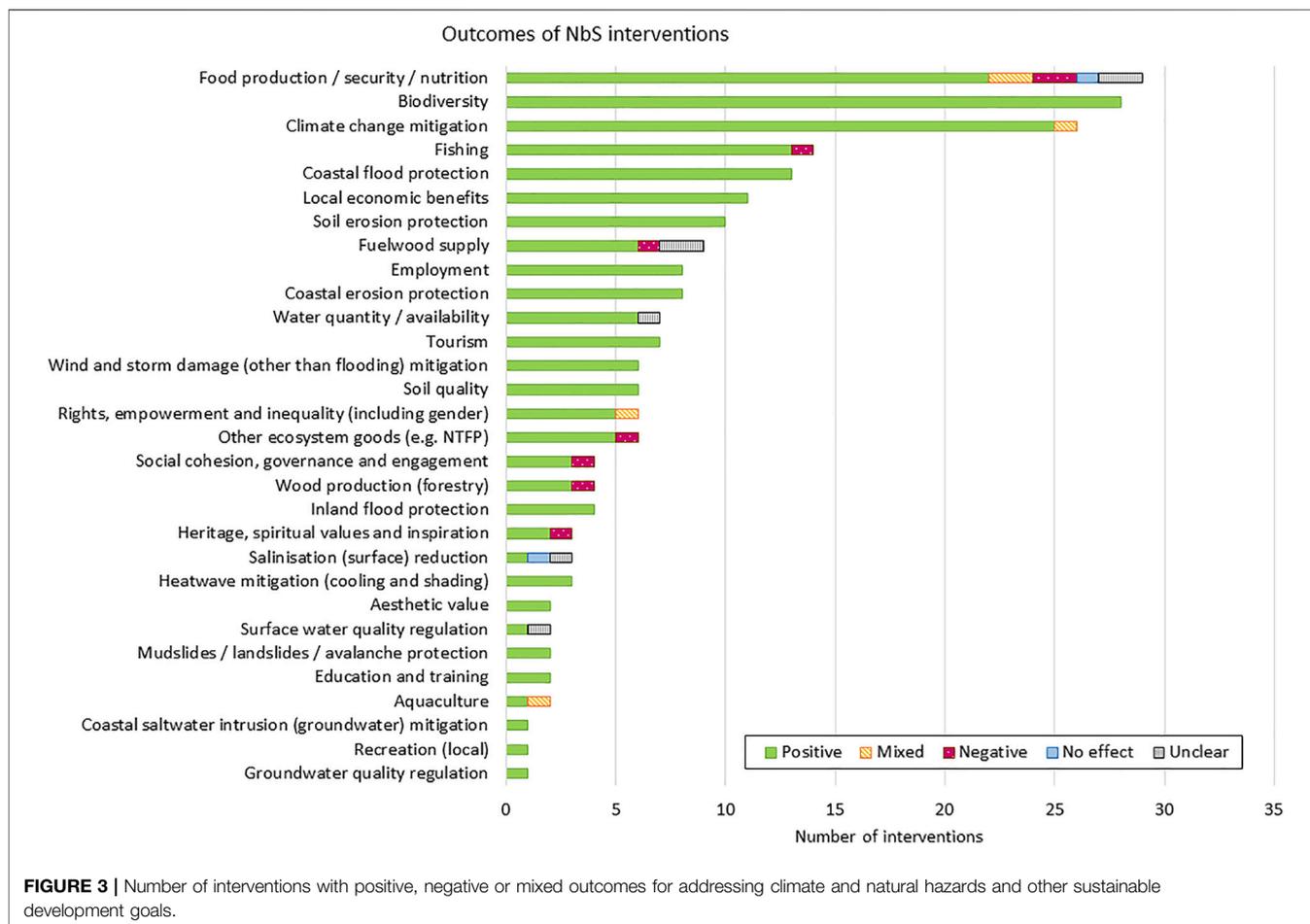
Ecosystem	Type of intervention	No	Description
Coastal	Mangrove protection and restoration	15	Protection of existing or restored mangroves or replanting of mangrove seedlings for coastal protection, livelihoods and biodiversity. Most (9) studies are in the Sundarbans reserve, an area of over 600,000 ha which has been protected as a Ramsar site since 1992, but some (6) assess restoration initiatives in the Chittagong region or along the south coast
	Oyster reef creation	1	One experimental site on the south coast, to assess the benefits for coastal protection
	Shoreline conservation	1	Mixed conservation measures in Cox's Bazar - Teknaf Peninsula and Sonadia Island Ecologically Critical Areas (ECAs) including protecting mudflats and the rocky intertidal zone and conservation of sea turtles, to benefit fisheries
	Sand dune revegetation	2	Replanting native vegetation in Cox's Bazar - Teknaf Peninsula and Sonadia Island ECAs for erosion protection
	Coastal shelterbelt	2	Planting of strips of coastal trees to protect from storm surges, cyclones and coastal erosion
Inland wetlands	Swamp forest protection and restoration	4	Planting native swamp forest trees in the Haor wetlands for flood and erosion protection, livelihoods and biodiversity
	Wetland protection and restoration	8	Protecting and restoring the Haor wetlands, e.g. re-excavating silted up areas that dry out in summer, to protect fisheries
	Fishery management	4	Regulating fishing and preventing 'poison fishing' to avoid over-exploitation, in the Haors
	Floating gardens	2	Growing vegetables on mats of floating wetland vegetation (mainly water hyacinth) when farmland is inundated
	Bioremediation	4	Use of water hyacinth to remediate water pollution in the Haors; and experiments with constructed wetlands or soil fungi to remove arsenic from water and soils
Terrestrial forests, shrub and grass	Terrestrial forest protection and restoration	9	Protection and restoration of the Chittagong Hill Tracts forests, to protect from erosion and sustain livelihoods. Also planting trees to stabilize embankments in the Haors
	Community forestry	4	Vulnerable local people co-manage plantations or native forests and in return are allowed to harvest them sustainably
	Forest plantation	1	Experiment to assess carbon storage and sequestration
	Grass and shrub cover	2	Use of native grasses and shrubs on embankments and around homesteads to protect against erosion
Agroforestry and homegardens	Agroforestry	6	Planting rows of fruit, timber or fuelwood trees amongst other crops; helps to stabilize soil on steep slopes
	Homegardens	7	Small areas around homesteads, growing a diverse mix of trees, shrubs, vegetables and other plants for food, timber, fuel, ornamental and medicinal use
Cropland	Conservation agriculture	15	Experiments or large scale field trials of conservation agriculture techniques including reduced tillage, retaining crop residue, adding organic matter (e.g., manure, compost) to soils, cultivating rice without flooding the field, increasing crop diversity, and integrated pest management. Aimed at increasing resilience to climate change (especially droughts) and reducing the use (and cost) of agro-chemicals
	Rainwater harvesting	1	Excavating ponds to store water for use during the dry season
Urban	Urban green space	1	Production of food and other goods in rooftop gardens and other open spaces in Dhaka

and Hussain, 2019). Low income households are highly dependent on forests for fuelwood and timber, and over-harvesting is causing severe forest degradation which reduces carbon storage (Yong Shin et al., 2007). For example, one study found that plots reforested with species that were valued as wood fuel showed much lower levels of carbon storage than those using other species, due to harvesting by local people. It was suggested that providing secure land tenure and clean energy options for indigenous communities could enable more sustainable management of forest resources with benefits for carbon storage (Yong Shin et al., 2007).

Forests managed for production are only categorized as nature-based solutions if they provide biodiversity benefits (compared to business-as-usual) and are co-implemented with local communities. Carbon storage will be offset by emissions from wood extracted for fuel or short-lived products such as paper. Estimates of carbon storage are lower than for natural forests, ranging from 200 tC/ha for roadside social forestry plantations (Rahman et al., 2015) to 118 tC/ha for homegardens (Nath et al., 2015) and 31–37 tC/ha for agroforestry (Hanif et al., 2015). However homegardens in Bangladesh stored more carbon than those in India, which could be due to their higher tree density and diversity (Nath et al., 2015).

Conservation agriculture can play an important part in reducing emissions by improving soil health and soil carbon. This enables inputs of mineral fertilizers to be reduced and thus also cuts nitrous oxide emissions (Islam et al., 2011; Alam et al., 2020), and it may reduce the need for pumped irrigation, saving carbon emissions from fuel use (Begum et al., 2018). However, switching to 100% organic fertilizers may not be the best strategy as although it increases soil carbon, it may reduce yields and increase methane emissions (Begum et al., 2018). Also, cow dung and crop residues are in demand as fuels

FIGURE 3 | Number of interventions with positive, negative or mixed outcomes for addressing climate and natural hazards and other sustainable development goals.

(Begum et al., 2018). Integrated methods that combine organic fertilizers with reduced tillage, increased residue retention and lower use of synthetic fertilizers can successfully maintain yields whilst cutting costs and emissions (Islam et al., 2011; Begum et al., 2018).

Non-puddled transplanting of rice is an important option for reducing methane emissions. It involves strip tillage (tilling only the strips to be planted rather than the whole field) followed by planting into saturated soil, rather than the usual practice of planting into a ploughed and flooded field (Bell et al., 2019). This cuts the total lifecycle greenhouse gas emissions of rice production by between 16 and 31% depending on the level of crop residue (straw) retention (Bell et al., 2019). Residue increases soil carbon storage and crop yield, but this is offset by higher methane emissions as the incorporation of residue into the soil stimulates the activity of methane-producing bacteria (Alam et al., 2019).

Coastal Floods, Erosion, and Salinization

Bangladesh is one of the most vulnerable countries in the world to coastal hazards (Shi et al., 2016). A large proportion of the population live in low-lying coastal areas on a funnel-shaped delta with a high tidal range, putting them at high risk from cyclones and storm surges (Das et al., 2010; Rahman et al., 2019) which cause extensive wind and flood damage. In addition,

coastal areas are often lost to erosion, and suffer from salinization of groundwater and agricultural land due to seawater intrusion and frequent flooding. We found 24 outcomes for coastal protection: 22 positive, 1 mixed and 1 unclear. Most (15) were for mangrove protection and restoration.

Mangroves have provided a natural barrier to coastal hazards for centuries. They are estimated to protect 1.1 million to 3.5 million people in Bangladesh from coastal flooding during cyclones (Akber et al., 2018), avoiding damage worth at least US$1.56 billion per year on average (Menéndez et al., 2020). Villages protected by mangroves had only about half of the monetary loss from flood and wind damage associated with cyclone Sidr, compared to other villages (Akber et al., 2018). Even a 100 m deep coastal shelterbelt of healthy mangroves can reduce storm surge velocity by up to 92%, protecting embankments from costly damage (Dasgupta et al., 2019), and a double shelterbelt of mangrove and *Casuarina* trees, 200–300 m in depth, can reduce storm surge height by up to 22% and velocity by up to 49% (Das et al., 2010).

The Forest Department of Bangladesh started planting mangroves along the whole coastline in 1966, initially aiming to boost protection against cyclones and storm surges, and later to stabilize newly accreted (char) land so that it can be used for agriculture (Iftekhar and Takama, 2008). Planting with mangroves greatly increased the ratio of accretion to erosion,

TABLE 4 | Number of positive outcomes reported in the literature reviewed for each type of NbS.

		GHG reduction	Coastal floods, erosion and salinization	Inland floods and erosion	Wind damage	Heatwaves	Water security	Food security	Wood, fuel and NTFP	Cultural benefits	Socio-economic benefits	Biodiversity	Total
Coastal	Mangrove protection and restoration	7	15	2	3	1	0	4	6	3	15	4	32
	Oyster reef creation	0	1	0	0	0	0	0	0	0	0	0	0
	Shoreline conservation	0	0	0	0	0	0	1	0	0	0	1	2
	Sand dune revegetation	0	3	0	0	0	0	0	0	0	0	1	1
	Coastal shelterbelt	1	2	0	1	0	0	0	1	1	1	1	4
Inland wetlands	Swamp forest protection and restoration	1	0	2	0	0	0	3	0	0	4	4	11
	Wetland protection and restoration	0	0	0	0	0	0	5	0	0	9	6	20
	Fishery management	0	0	0	0	0	1	3	0	1	3	4	11
	Floating gardens	0	0	0	0	0	0	2	0	0	1	0	3
	Bioremediation	0	0	0	0	0	2	1	0	0	0	0	1
Terrestrial forests, shrubs and grass	Terrestrial forest protection and restoration	2	0	7	1	1	0	2	0	0	5	3	10
	Community forestry	1	1	0	0	0	0	1	0	0	2	1	4
	Forest plantation	1	0	0	0	0	0	0	0	0	0	0	0
	Grass and shrub cover	0	0	2	0	0	0	0	0	0	0	0	0
Agroforestry and homegardens	Agroforestry	2	0	1	1	0	0	4	3	0	3	2	12
	Homegardens	1	0	2	0	1	0	1	2	0	4	1	8
Cropland	Conservation agriculture	6	0	0	0	0	4	13	0	0	3	0	16
	Rainwater harvesting	0	0	0	0	0	1	0	0	0	0	0	0
Urban	Urban green space	0	0	0	0	0	0	3	2	0	0	0	5
Total		22	22	16	6	3	8	43	14	5	50	28	140

TABLE 5 | Key examples of evidence on the target outcomes of NbS cited in *Effectiveness of Nature-based Solutions for Addressing the Target Outcomes*

Outcome	NbS	Selected examples of outcome evidence	Reference
GHG reduction	Protecting and restoring mangroves	Carbon storage: 219 tC/ha	Rahman et al. (2017)
		Carbon storage: 257 tC/ha, of which 63% below ground in the soil and roots	Abdullah-Al-Mamun et al. (2017)
		Carbon storage (global averages): 400 tC/ha for oceanic mangroves; 2000 tC/ha for estuaries. Average for Indo-Pacific region: 1,023 tC/ha. Conversion to aquaculture by excavating >2 m of sediment can release 70 tC/ha. Sequestration: 1.5 to 6 tC/ha/y (global range)	Global review. Chow, (2018)
		Sequestration: 1.7 tC/ha/y, four times more than mature land-based forests. Offset 1.5% of Bangladesh's fossil fuel CO_2 emissions in 2014	Global review. Taillardat et al. (2018)
		Sequestration: Sundarbans sequestered 4.8 Mt CO_2/year from 1997 to 2010. Offset 10% of Bangladesh's CO_2 emissions	Abdullah-Al-Mamun et al. (2017)
	Plantations	Carbon storage: Roadside social forestry plantations in south-western Bangladesh store almost 200 tC/ha although this is less than native woodlands	Rahman et al. (2015)
	Agroforestry	Sequestration: 115–135 tCO2/ha/y (equivalent to 31–37 tC/ha/y) 7 years after planting for three typical fast-growing species	Hanif et al. (2015)
	Homegardens	Carbon storage: average 118 tC/ha in above-ground biomass, much higher than homegardens in India, thought to be due to higher tree density	Nath et al. (2015)
		Carbon storage: Soil organic carbon 0.12–1.65%; positively correlated with tree species diversity and density, probably because more diverse systems are more productive due to niche complementarity	Islam et al. (2015)
Coastal floods, erosion and salinization	Protecting and restoring mangroves	820 km^2 and 1.1 million people protected from coastal flooding during tropical cyclones and other storms by mangroves in Bangladesh, avoiding damage worth US$1.56 billion per year on average	Global model Menéndez et al. (2020)
		3.5 million people protected by mangroves in Sundarbans	Survey of Sundarbans Akber et al. (2018)
		Villages protected by mangroves had about half of the monetary loss from flood and wind damage to houses, property, crops, livestock and aquaculture stock associated with cyclone Sidr (TK 69,726, US$1,025 per household), compared to villages not protected by mangroves	
		Even a 100 m deep strip of healthy mangroves can reduce storm surge velocity for a storm of the same magnitude as cyclone Sidr by up to 92%, providing significant savings in maintenance costs by protecting embankments from damage	Model Dasgupta et al. (2019)
		Char land areas in the Barisal and Chittagong regions planted with mangroves experienced 37.2 times more accretion than erosion between 1973 and 1989 and 4.7 times more from 1989 to 2010, compared to only 1.6 and 1.3 times more accretion than erosion in areas that were not planted. For lands that were newly accreted in 1989, 31% of non-plantation land had eroded by 2010 compared to only 10% of plantation land	GIS analysis Chow, (2018)
		The CBA-ECA project planted 361 ha of mangrove and 62 ha of sand dune vegetation to protect the flora and fauna of the Cox's Bazar-Teknaf Peninsula and Sonadia Island ECAs. Community-based organizations worked with local and national government and law enforcement agencies to revert illegal shrimp farms into mangrove forest	Long term project report DoE, (2015)
		The CREL project supported planting of 565,000 mangrove seedlings on 512 ha, estimated to deliver US$485 million of storm protection services as well as co-benefits totaling US $684 million annually, and planted 20 ha of sand dunes with 562,000 seedlings of Nishinda and Dholkolmi (*Ipomoea carnea*) to reduce erosion and storm surge impacts, helping to maintain the integrity of the island, and creating habitats to support indigenous species	Long term project report (Winrock International, 2018)
	Coastal shelterbelts	Double coastal shelterbelts of mangrove and *Casuarina* trees, 200–300 m in depth, can reduce storm surge height by up to 22% (1.4 m) and surge velocity by up to 49% (1.2 m/s) for an event like Cyclone Sidr. Mangroves have a higher drag due to their aerial root structure, but densely planted *Casuarina* can be more effective for very high surges Das et al. (2010)	Model Das et al. (2010)
Inland flooding and erosion	Agroforestry	Cultivation of cash crops such as ginger causes soil erosion that costs about 11% of the total production costs, but agroforestry can turn this loss into a gain of about US$26 ha/year, as the soil-formation rate exceeds the erosion rate	Rasul, (2009)
		In the MACH project (Table S5), switching from planting pineapples along contours rather than in rows up and down slopes also allowed denser planting and resulted in increased fruit size, thus increasing the farmers' income and food security. The contour plots increased profits by 140% over 3 years, to Tk 128,600 per acre, which is Tk 74,990 per acre more than the traditional cultivation system	Long term project report MACH-II, (2007a), MACH-II, (2007b)

TABLE 5 | (*Continued*) Key examples of evidence on the target outcomes of NbS cited in *Effectiveness of Nature-based Solutions for Addressing the Target Outcomes*

Outcome	NbS	Selected examples of outcome evidence	Reference
	Protecting and restoring terrestrial forests	Catchments with regenerating or planted trees and other vegetation had 3–4 times less soil erosion, 4–35 times less nutrient loss, 16% less annual runoff and the peak flow was seven times lower than a catchment that had been cleared for agriculture	Paired catchment experiments Gafur et al. (2003)
		Local tree species with deep tap roots could successfully stabilize steep slopes at risk of landslides although this is only suitable for slopes of less than 70°	Model Islam and Rahman, (2019)
		In the Haor basin, Government agencies, donors, NGOs and local communities collaborate to plant locally raised seedlings of flood-tolerant plants, particularly Hijal (*Barringtonia acutangula*) and Koroch (*Pongamia pinnata*). 125,000 seedlings were planted onto kanda (raised land) under the Tanguar Haor Project (2006–2016), 18,450 seedlings were planted in 17 ha at six sites at Hakaluki Haor under the CBA-ECA project (2011–2015), and 112 ha were restored under the CREL project In Hakaluki Haor, 11 submersible embankments with 'green belts' of indigenous tree species were established	Long term project reports DoE, (2015), IUCN Bangladesh, (2016), Winrock International (2018)
	Growing herbaceous plants	Villagers in Chanda Beel are growing low plants such as *Sesbania* (doincha), grass and "dholkolmi" (*Ipomea carnea*, morning glory) and heaping piles of rotten water hyacinth around homesteads to prevent soil erosion during floods, as well as planting more trees in fields	(Reid and Alam, 2017)
Wind damage	Protecting and restoring mangroves	The cost of repairing and reconstructing houses due to combined wind and flood damage Cyclone Sidr was lowest (TK 27,043) for a site protected by mangroves compared to TK 82,246 for a site with no mangroves, and damage to trees was also lower, with 36% of trees damaged compared to 56% for the site with no mangroves	Survey Akber et al. (2018)
	Coastal shelterbelt	A 19 year old 50 m *Casuarina* shelterbelt was thought to have reduced wind speed (from 4.16 to 2.88 on a scale of 1–5) and increased the size of sand dunes (from 1.86 to 2.74)	Survey of perceived impacts Miah et al. (2013)
	Homegardens	Taller trees are grown at the boundary where they provide protection against wind but do not shade the other plants, and will not fall on the house if blown over. On the beach and hillside, owners preferred coconuts (chosen by 53% of owners), supari (45%), mango (42%) and jackfruit (25%), due to their high survival rate, strong root systems, strong stems, and low weight/light canopy which reduces the wind load on trees and prevents damage if they are blown over. However, on the mudflat island of Shahparir dwip owners preferred *Acacia* (50%), raintree (*Samanea saman*, 40%), jhau (*Casuarina equisetifolia*, 33%) and mahogany (28%) because of their strong and spreading root systems or deep taproots	Survey in Cox's Bazar Nath et al. (2015)
Water security	Conservation agriculture	Strip planting into un-tilled ground increased the water productivity of wheat by 60% compared to conventional tillage, from 1.25 to 2.06 g of grain per kg of water. Minimum soil disturbance and retention of crop residue slow evaporation, aided by the cooler temperatures under retained residue	Bell et al. (2019)
		Conservation agriculture techniques increased irrigation water productivity by 25% in rice-wheat and rice-maize systems, increasing the resilience of farmers to unpredictable rainfall patterns	Islam et al. (2019)
Food security	Conservation agriculture	A 10-year program involving over 6,000 farmers in four districts found that strip planting increased yields by up to 28% for lentil (*Lens culinaris*) and 6% for wheat (*Triticum aestivum*). Strip planting cut cultivation costs by 75%, labor requirements by 50%, irrigation water requirements by 11–33% and fuel costs by up to 85%, and increased profits by between 47% for lentil and 560% for mustard (*Brassica juncea*). Researchers on this program worked with farmers and equipment supplies to develop a lightweight reduced tillage planting machine; they estimated that if this was used by 2.5% of farmers in Bangladesh it would generate US$21–38 million per year from increased yield and reduced production costs	Bell et al. (2019)
		Increased yields for wheat and maize but not rice, lentil (*Lens culinaris*) and mung bean	Islam et al. (2019); Rashid et al. (2019)
	Fishery management and wetland restoration	The MACH project (**Supplementary Table S5**) supported local resource management organizations in re-stocking nearly 1.2 million fish (mostly juveniles) of 15 native species, which enriched fish production and biodiversity. Restoration of critical habitats can have a significant impact on catches across a much larger area, for example by excavating silted-up wetland pools in the dry season which can then be used in irrigation and to support breeding habitat for fish, and thus to contribute to food and water security. Restoration of wetland habitats and sanctuaries more than doubled fish catches, from 144 kg/ha in 1999 to an overall average of 327 kg/ha by 2007. Fish consumption of the village households around these wetlands increased by about 45% on average throughout the project period, and the landless benefited as much as larger landowners	Long term project report MACH-II, (2007a)

TABLE 5 | (Continued) Key examples of evidence on the target outcomes of NbS cited in *Effectiveness of Nature-based Solutions for Addressing the Target Outcomes*

Outcome	NbS	Selected examples of outcome evidence	Reference
	River restoration and management	Five fish sanctuaries were created in different beels (perennial water bodies) of Tanguar Haor, 12 under the CBA-ECA Project and 63 under the MACH project. These helped to increase fish supply and other aquatic resources, and enrich biodiversity, employment and tourism. Fish catches in sample areas increased from 171 kg/ha in 2013–14–277 kg/ha in 2015–16	Long term project reports: DoE, (2015) IUCN Bangladesh, (2016), MACH-II, (2007a), Winrock International (2018)
		The River Halda in Chittagong is the only freshwater tidal river in the world with the right ecological conditions for the spawning of major Indian carp species, such as *Catla, Labeo rohita, Cirrhimus mrigala and Labeo calbasu*. Fish eggs and fry are gathered and sold to underpin aquaculture across the whole country. However the river is under threat from over-fishing, pollution, saline intrusion, excessive sand quarrying and unregulated construction of sluice gates for irrigation. Local people recognized the river's value and were willing to contribute their time and money to help conserve the services it provides, although there was a substantial gap between their willingness-to-conserve (Bangladesh Taka 54 million) and the value of the services provided by the river. This led the authors to recommend that community-based management, perhaps supported by a Payment for Ecosystem Services approach, should be applied to the Halda and to other rivers throughout Bangladesh	Kabir et al. (2015)

and cut the risk of erosion loss by a third (Chow, 2018). Long term community-based adaptation projects have involved local communities in planting mangroves and re-vegetating sand dunes to protect against coastal flooding and erosion (DoE, 2015; Winrock International, 2018; **Table 5**).

Despite the success of these initiatives, both existing and replanted mangroves have been extensively cleared for housing, infrastructure, agriculture and aquaculture, and degraded due to over-extraction of timber and fuelwood. Timber harvesting from mangroves was banned in 1991; this reduced the short-term benefits for local people but was expected to improve coastal protection, fish production, biodiversity and carbon storage (Abdullah-Al-Mamun et al., 2017). However such bans are not always effective, due to corruption and weak enforcement (Iftekhar and Takama, 2008; Abdullah-Al-Mamun et al., 2017; Rahman et al., 2018). Mangroves are also threatened by climate change impacts including fresh water flow reduction, sea level rise, salinity increase and storm damage (Ahammad et al., 2013; Abdullah-Al-Mamun et al., 2017; Chow, 2018; Rahman et al., 2018). Restoration should use species that are well adapted to current and future local conditions, and replanting may be necessary after a few years because there can be a high failure rate (Dasgupta et al., 2019).

Bangladesh lacks coral reefs, but one study showed that artificially created **oyster reefs** could help to reduce coastal erosion, trap suspended sediment, and support saltmarsh expansion (Chowdhury et al., 2019). However, their potential may be limited due to the high turbidity of Bangladesh's coastal waters.

Inland Flooding and Erosion

Floods, landslides, and soil erosion are severe problems in Bangladesh. In the Chittagong Hills, steep slopes, heavy rainfall, poor soil and intensive cultivation for cash crops is leading to soil erosion of over 100 t/ha/year, loss of soil nutrients, falling crop yields, landslides, and sedimentation of reservoirs (Rasul, 2009). This is exacerbated by changes in traditional slash-and-burn cultivation ('jhum'), as population pressures have shortened the fallow period during which secondary forest usually regenerates from 6 to 7 years to just 3–4 years (Gafur et al., 2003; Nath et al., 2005; Rasul, 2009). We found 16 examples of how NbS can address these hazards, and one unclear outcome.

Protecting and restoring forests plays a key role. Soil erosion was found to be three to four times lower and peak flow seven times lower in a forested catchment than a cleared catchment (Gafur et al., 2003), and modelling indicates that trees with deep tap roots could prevent landslides on slopes less than 70° (Islam and Rahman, 2019). **Agroforestry** can reverse soil loss, as the soil-formation rate can exceed the erosion rate (Rasul, 2009). Contour planting (planting trees across slopes) can be particularly effective, and can increase yields, income and food security (e.g., in the MACH project, MACH-II, 2007a,b). In the Haor Basin, community-based adaptation initiatives are restoring **freshwater swamp forests** and planting **trees on embankments** to protect villages on 'kanda' (raised land that becomes islands when the seasonal wetlands flood) from erosion due to wind-driven wave action (DoE, 2015; IUCN Bangladesh, 2016;

Winrock International, 2018). Villagers also grow low plants and heap piles of rotten water hyacinth around homesteads to prevent soil erosion during floods (Reid and Alam, 2017).

Wind Damage

Cyclones and other tropical storms cause damage from high winds as well as flooding. Trees can help to protect against this, although they can also cause damage if they are blown over (Nath et al., 2015) and, conversely, forests and mangroves can themselves be damaged in storms (Dasgupta et al., 2019). We found six positive outcomes of NbS for addressing wind damage.

Protection by **mangroves** in the Sundarbans reserve significantly reduced the cost of repairing houses due to combined wind and flood damage (Akber et al., 2018), and **coastal shelterbelts** of *Casuarina* trees were also perceived to be effective in reducing wind speed and increasing the size of sand dunes (Miah et al., 2013). In **homegardens**, a survey found that taller trees are grown at the boundary where they provide protection against wind but do not shade the other plants, and will not fall on the house if blown over (Nath et al., 2015). On exposed beach and hillside locations, species such as coconuts were preferred due to their strong stems, low weight, and light canopy, which reduced the wind load on trees and reduced damage if they fall, while species such as *Acacia* were chosen on mudflats because of their strong and spreading root systems.

Heatwaves

Only two of the studies retrieved in our review referred to NbS for protecting against heat, and neither provided robust evidence. In the Haor basin, villagers value the forest for providing shade and cooling the air, and they are also planting more fruit trees at their homesteads for shade during heatwaves (Reid and Alam, 2017). However, native trees such as mango and jackfruit are susceptible to hailstorm damage, so they are being replaced with fast-growing and storm-resistant non-native timber trees such as teak, eucalyptus and acacia (Reid and Alam, 2017), so this action might not be classified as a NbS as there could be adverse biodiversity impacts. On the coast, local people planted salt-tolerant mangrove trees on land degraded by a saline storm surge where all the other trees had died, to provide protection from summer heat (Imam et al., 2016). The evidence in these studies was based on the perception of the villagers who carried out the intervention.

Water Security

Although Bangladesh experiences extremely heavy rainfall in the monsoon season, droughts and water shortages are a growing problem in the dry season (Sayed et al., 2020), due to climate change, over-abstraction of water for human use, soil degradation, water pollution and salinization.

Ten interventions were associated with outcomes for water security: 8 positive and 2 unclear. Four of the positive outcomes were from **conservation agriculture**, where improving soil structure and retaining crop residue can reduce evaporation and enhance soil water infiltration and storage, reducing the need for irrigation (Alam et al., 2017; Bell et al., 2019; Islam et al., 2019; Sayed et al., 2020). For example, these techniques increased the water productivity of wheat by 60% (Bell et al., 2019) and increased

irrigation water productivity by 25% (Islam et al., 2019), increasing the resilience of farmers to unpredictable rainfall patterns.

Rainwater harvesting mainly involves engineered options such as installation of rooftop tanks. However, a study in the Barind Tract described how re-excavation of silted-up ponds and beels (permanent wetland waterbodies) allowed rainwater storage and infiltration to recharge a depleted aquifer, so that the community now has water all year round rather than only for 4–5 months of the year (Rahaman et al., 2019).

Four interventions addressed water pollution, which seriously affects both surface water and groundwater in Bangladesh. We found evidence that **constructed wetlands** could be used to help tackle the problem of groundwater pollution by arsenic, which affects over 1.5 million wells used by 35 million people in Bangladesh. Experiments indicate that water from wells could be passed through a series of wetlands containing river sand and planted with bulrush (*Typha latifolia*), which would reduce arsenic concentrations to the WHO safe limit (Schwindaman et al., 2014). Two studies mentioned the potential role of water hyacinth for removing water pollution in inland wetlands, but neither provided robust data (MACH-II, 2007a; MACH-II, 2007b; Reid and Alam, 2017).

Food Security

Food security accounted for 43 of the 140 positive outcomes identified in the review, and nine mixed, negative, neutral or unclear outcomes. Conservation agriculture was the most frequently cited NbS, but others included agroforestry, homegardens, wild food in protected forests, and the role of protected and restored mangroves and inland wetlands in supporting fisheries.

Smallholders face severe challenges in Bangladesh, as soil fertility is declining, rainfall is becoming more unpredictable and the cost of agrochemicals, irrigation and fuel is increasing. **Conservation agriculture** has been extensively studied as a way of improving soil health and water storage capacity, with a focus on adapting the approach for the rice-based rotations that predominate in Bangladesh. The key benefit for food security is that conservation agriculture enables inputs of mineral fertilizers and irrigation to be reduced without loss of yield (Islam et al., 2011; Alam et al., 2020), and this in turn increases profitability (Aravindakshan et al., 2015; Gathala et al., 2016). The papers stated that the key is to apply integrated science-based approaches that combine conservation agriculture techniques with reduced (but not zero) use of synthetic fertilizers, to maintain yields whilst cutting costs (Islam et al., 2011; Begum et al., 2018).

For example, a 10-year program involving over 6,000 farmers found that strip planting increased yields by up to 28% and cut cultivation costs by 75%, labor requirements by 50%, irrigation water requirements by 11–33% and fuel costs by up to 85%, increasing profits by 47–560% for different crops (Bell et al., 2019) (**Table 5**). Researchers on this program worked with farmers and equipment supplies to develop a lightweight reduced tillage planting machine; they estimated that if this was used by 2.5% of farmers in Bangladesh it would generate US\$21–38 million per year from increased yield and reduced production costs.

Similarly, **integrated pest management**, which combines non-chemical methods of pest control (such as manual removal of pest

eggs, and provision of perches for birds) with reduced application of pesticides at the economic threshold level (at which the value of the crop destroyed exceeds the cost of controlling the pest), can increase yields and save money compared to conventional heavy pesticide use, while reducing pollution and health impacts from pesticide poisoning (Alam et al., 2016).

Agroforestry offers a method of increasing food, fuel and timber production despite shrinking available land and a growing population, by making use of vertical space (Hanif et al., 2015). It can help to reduce the negative environmental impacts of food production such as soil erosion, water pollution and (if native tree species are used) biodiversity loss, and can help to restore degraded land. The first two Community Forests in Bangladesh were established on deforested land in the Chittagong Hill Tracts that the Forest Department had already tried to replant several times but without success, due to lack of maintenance and encroachment for farming by local people. The land was given to local landless or almost landless people, who first planted eucalypts and fruit trees, and later shifted to native forest species. Sale of tree products improved their incomes and enabled them to diversify to other income sources, relieving pressure on local natural forests, but as they become less dependent on forest resources it remains to be seen whether this reduces their incentive to conserve and replant the community forest (Mohammed et al., 2016). Agroforestry could also potentially help to restore land that has been degraded by saline intrusion, although there is a risk that it could exacerbate the problem by concentrating salts in the root zone (Wicke et al., 2013).

Homegardens are widespread and play a vital role in food security in Bangladesh. One study found that applying a year-round rotating system of different vegetables and fruit trees, chosen through a participatory approach using local traditional and indigenous knowledge, could more than double annual production, improve nutrition, increase household income, alleviate poverty and provide employment and empowerment for female family members (Ferdous et al., 2016). In dense urban areas, rooftop gardens can play a key role; 35% of properties surveyed in one part of Dhaka had rooftop gardens providing a wide range of fruit and vegetables (Zinia and McShane, 2018).

Floating gardens are a traditional approach to cultivation in some wetland areas, and have more recently been introduced to the Haor basin. Mats of floating wetland vegetation (mainly water hyacinth, which is an invasive non-native species) are used as the base for vegetable gardens in the wet season when farmland is inundated, and the rotting mat is then used to fertilize the soil in the dry season when the water recedes. This can help families to produce food all year round, reducing the need for unsustainable harvesting of wild resources to sustain livelihoods (Irfanullah et al., 2008).

Wild food resources are important to many low-income households. People living closer to the Sundarbans mangrove forest have higher levels of dietary diversity, partly due to direct consumption of bushmeat, although the authors noted that bushmeat harvesting for subsistence often coexists with commercial bushmeat trades that may threaten endangered species (Baudron et al., 2019).

Forest ecosystem services can also contribute positively to food production in nearby cropland. A survey of 275 households in the Chittagong Hill Tracts found that households closer to forests were more likely to have homegardens and own livestock, and had higher fruit consumption and higher dietary diversity as a result. The nearby forest was thought to support crop production in homegardens through maintenance of soil fertility, micro-climate regulation, and pollination (Baudron et al., 2019). The benefits of these existing forests are a proxy for the benefits that would continue to be delivered through protecting and/or restoring the forests in future. However, protecting or restoring ecosystems such as forests and mangroves can reduce the area available for food production, potentially leaving a 'food gap' where an area is unable to produce enough food to meet local demand (Hoque et al., 2020). To address this, it has been suggested that, for example, coastal areas targeted for NbS to provide hazard protection could receive food subsidies from surplus food produced in other areas further inland (Hoque et al., 2020).

Sustainable fishery resource management has long been practiced by communities in the freshwater wetlands of Bangladesh. Community-based projects have brought all the remote beels (permanent pools within the seasonal wetland) under one management practice, allowing the community to harvest fish to a sustainable level under certain conditions determined by biodiversity conservation goals (IUCN Bangladesh, 2016). This supports poor people's rights and access to resources, as well as boosting food and nutrition security, employment and biodiversity. In the Tanguar Haor project, endorsement of a 'core zone and buffer zone' approach by the government was a significant achievement which established the rights of the poor to access fisheries across the wetland, and reduced illegal harvesting (IUCN Bangladesh, 2016). In addition, the projects build the capacity of the community by developing income generating and community management skills, raising awareness of wetland resource issues and understanding the value of biodiversity conservation (IUCN Bangladesh, 2016). Community-managed fish sanctuaries have also been created in deeper parts of the wetland, where fishing and collection of other aquatic resources are restricted or totally prohibited. In Hakaluki Haor, fish sanctuaries were established in two beels by using katha (bamboo and tree branches) to create breeding grounds and food supply for the fish and protect from illegal fishermen. This helped to increase fish catches from 171 kg/ha in 2013–14 to 277 kg/ha in 2015–16, while enriching biodiversity, employment and tourism (Winrock International, 2018; **Table 5**). The MACH project also supported local resource management organizations in re-stocking nearly 1.2 million fish of 15 native species, and restoring critical wetland habitats. This enriched fish production and biodiversity, more than doubling fish catches, and increasing fish consumption in local villages by about 45%, with landless people benefiting as much as larger landowners (MACH-II, 2007a).

River protection, restoration and sustainable management can sustain and enhance essential services including provision of fish and fresh water. For example, the River Halda is the only river in the world where major Indian carp species can spawn (Kabir et al., 2015). Fish eggs and fry are gathered and sold to underpin aquaculture across Bangladesh. However, the river is under threat from over-fishing, pollution and other human activities. A survey found that local people were willing to contribute their time and money to help conserve the river, although their willingness-to-conserve was less than the value of the services it provided (Kabir

et al., 2015). The authors recommended that community-based management of rivers could be supported by a Payment for Ecosystem Services approach.

Wood, Fuel, and Non-Timber Forest Products

Forests are a vital source of wood, timber and other products for local people in Bangladesh, although over-exploitation has led to widespread forest degradation (Yong Shin et al., 2007). There were 19 outcomes related to this, of which three were negative, all from a study of the impacts of forest protection in the Chittagong Hills (Miah et al., 2014). This found that local households generated an average revenue of Bangladesh Taka 13,473 per year from gathering timber, firewood, bamboo, medicinal plants, bushmeat and nuts, as well as being dependent on these goods for their own use. Dependence on the forest for medicinal, religious and food purposes was felt to be non-negotiable, while some people were prepared to forego extraction of timber, bamboo and vegetables if appropriate cash compensation or alternative livelihoods were provided. The authors recommended that providing secure land tenure for the indigenous communities could help to establish more sustainable management of the forest resources, which were perceived to be severely degraded due to over-extraction.

Many NbS interventions attempt to manage this conflict by implementing participatory sustainable management approaches. One example is the **social forestry** program, which was launched by the Bangladesh Forest Department in 1989 to support forest restoration, agroforestry, village woodlots, and roadside plantations (Rahman et al., 2015). Most of the roads in south-western Bangladesh are lined by social forestry plantations that are protected and managed by local landless and land-poor people, who are allowed to gather fuelwood and receive 40% of the proceeds after felling (Rahman et al., 2015). Similarly, in Hakaluki Haor, the 'green belts' of indigenous tree species established on embankments provide fuel wood and local economic benefits as well as reducing flood risk (DoE, 2015). Local communities are also allowed to gather branches for fuelwood from restored swamp forest when it is sufficiently mature, but there are agreements not to fell the trees (MACH-II, 2007a; IUCN Bangladesh, 2016).

Conflicts between different beneficiaries are illustrated by a case study of Nijhum Dwip, an uninhabited mudflat island that was planted with mangroves by the Forest Department and was later declared a National Park, due to its value for migratory birds (Iftekhar and Takama, 2008). However, around 700 households who had been displaced from their homes due to river erosion gradually settled on the island, leading to illegal encroachment and extraction of timber from the forest. Around a quarter of people interviewed on the island were highly dependent on forest resources, especially women and low-income households, and the forest also attracted tourists who boosted the local economy. Yet many residents wanted to convert the forest to agriculture, aquaculture or commercial forestry. Despite this, and in apparent contradiction, almost all thought that the forest should be better protected and that new mangroves should be planted. It was suggested that adaptive co-management involving local people could help to resolve these conflicts and trade-offs through sustainable use and equitable distribution of benefits.

Cultural Outcomes

We found only six cultural outcomes in the review, three related to the value of protecting the Sundarbans mangroves for aesthetic value, recreation and cultural heritage and spiritual inspiration (Rahman et al., 2018). Cultural heritage was also an important benefit of protecting the River Halda, which inspired local festivals, characteristic Sampan boats and the Halda Fada songs (Kabir et al., 2015). However, trade-offs were found for a shelterbelt of casuarina trees, which increased the aesthetic value of the area and its attractiveness for tourism, but also acted as a location for increased anti-social behavior such as theft (Miah et al., 2013). Finally, the CREL (Climate Resilient Ecosystems and Livelihoods) project (**Supplementary Table S5**) was estimated to deliver US$53 million of tourism and cultural services (Winrock International, 2018).

Socio-Economic Outcomes

There were 52 outcomes reported for socio-economic benefits: 50 positive, one negative and one mixed. These included local economic benefits (15), employment (8), tourism (8), rights, empowerment and inequality (8 positive, 1 mixed), education and training (6), and social cohesion, governance and engagement (5 positive, 1 negative).

Local economic benefits include increased profits from implementation of conservation agriculture or agroforestry, income from use of sustainably harvested natural resources (including social forestry), and support for livelihoods provided through community-based management programs. Tourism also provides benefits for local economies, through opportunities for eco-tourism or enhanced attractiveness of tourist destinations. For example, a coastal shelterbelt was perceived to have increased tourist visits to a beach, due to provision of shade and increased attractiveness (Miah et al., 2013). Employment benefits came from jobs created through habitat restoration and protection, or livelihoods sustained through better management of resources. Out of the 154 interventions, 42 explicitly targeted poverty reduction although only 12 of these provided clear evidence that poverty had been reduced as a result of the intervention, while one reported no effect and five had unclear evidence. There was one mixed outcome for a social forestry initiative where poor people were excluded because the land was illegally occupied by local elites (Muhammed et al., 2008).

Out of the 50 positive socio-economic outcomes, 33 came from the community-based initiatives described in the grey literature reports (**Supplementary Table S5**). These were generally initiated by government departments with support from international development or conservation NGOs. They aimed to conserve biodiversity and provide sustainable livelihoods for local people, through empowering and engaging the community to manage their wetland and forest resources sustainably, with a strong focus on reducing poverty and inequality (DoE, 2015). Community organizations were established, and local people were offered training in natural resource management and conservation techniques and supported to develop diversified livelihood options, including through skills training and establishment of micro-credit loan schemes. For example, the CREL project provided training and support for enterprise development to

60,000 households, of which 51,400 reported that they had adopted more resilient agricultural practices, and 38,500 were estimated to have enhanced their incomes by a total of over US$5 million. Over 8,000 poor women (73% of livelihood beneficiaries) were empowered through financial training, helping them to improve access to services and credit, increase asset ownership and play a greater role in decision-making. CREL also helped 45 community management organizations to develop governance and financial capacity, with 35 of these (79%) reporting that they were able to become recognized local implementing partners for government and donor programs, and 23 (52%) becoming able to generate sustainable income from charging visitors to enter their protected areas (Winrock International, 2018).

These capacity building activities were accompanied by community-led restoration and protection of the ecosystems on which the communities depend, such as restoring swamp forests, excavating dried up wetlands and re-stocking with fish, with community guards protecting the restored forests from illegal exploitation. Co-management approaches were established, along with mechanisms for sharing the benefits from natural resources, such as by distributing 60% equally to households involved in the initiative, 25% to the community-based organization, and 15% to the government as revenue (IUCN Bangladesh, 2016).

Community management can help to build social cohesion and provide opportunities for engagement, education and cultural enrichment. For example, community organizations established two bird sanctuaries in Tanguar Haor, and employed community guards to protect them from illegal hunting, providing opportunities for eco-tourism development. A nature club was also established to engage young people in conservation and raise awareness on the importance of maintaining the ecological integrity of the wetland (IUCN Bangladesh, 2016). In the CBA-ECA project, local people started to feel a sense of pride in having a bird sanctuary in their neighborhood, and this empowered them to resist illegal hunters (DoE, 2015).

Several studies noted the importance of protecting intact ecosystems in order to sustain the flow of benefits on which many households depend, especially the most vulnerable. For example, the Sundarbans mangroves were estimated to provide public goods worth US$ 1,135 per ha each year, greater than the net economic return from shrimp farming at US$ 713 per ha (Rahman et al., 2018). A land use model of the Lower Meghna River Estuary estimated that loss of forests and mangroves due to urban expansion resulted in loss of ecosystem services worth US$118 million from 1988 to 2018, and continuing with business as usual or prioritizing economic development will lead to further losses of US$41 or US$16 million respectively, while protection and restoration will deliver an additional US$131 million of benefits (Hoque et al., 2020).

Biodiversity Benefits

NbS should, by definition, support and preferably enhance ecosystems and their biodiversity. However, ecological outcomes were only explicitly reported for 28 interventions (all positive), and only four of these had robust evidence. Often the benefits were reported in terms of species richness or presence of iconic species, and in anecdotal terms with no clear methodology or baseline.

We aimed to screen out any interventions for which there was no obvious pathway for delivering ecological benefits, which would not be defined as NbS, but in several cases this was not clear. For example, social forestry plantations were found to contain 36 tree species from 17 families, but 94% of the biomass was from just four fast-growing timber species (Rahman et al., 2015). Similarly, it was reported that homegardens have the same tree species diversity as natural forests, but the species composition is different to natural forests, with a bias towards fruit, nut and ornamental trees, some of which are not native species (Bardhan et al., 2012). The ecological outcomes of these interventions would depend on the most likely alternative use of the land.

Nevertheless, we did find evidence of the role of NbS in supporting the biodiversity of the unique and threatened forests, mangroves and wetlands in Bangladesh. Many of these were related to the community-based management projects, which protect threatened habitats and species while also providing jobs and eco-tourism opportunities (**Supplementary Table S5**). For example, protection and restoration of Baikka Beel within Hail Haor resulted in an increase in wintering water bird populations from about 300 birds of 16 species in 2004 to 7,200 birds of 35 species in 2007 (MACH-II, 2007b). Similarly, rapid assessments in Nuniarchhara mangrove forest found 24 wildlife species in 2011–2013 (18 birds, 2 mammals, 1 reptile, 3 amphibians) compared to 14 bird species in 2007–2010, although it is not clear whether the earlier assessment looked for non-bird species. The report also notes that seven species of kingfishers were observed in more recent years, which indicates abundance of native fish, as well as some rare species such as the fishing cat and monkey, and Purple Swamphen (Kalim) bird.

Enabling Factors for Successful Implementation of Nature-based Solutions

Several enabling factors were reported to influence the successful implementation and governance of NbS. We have classified these into five groups: participatory delivery incorporating local knowledge; strong, transparent and equitable governance; access to finance; secure land tenure; and practical support such as training.

Participatory Delivery

The literature identifies a long tradition of research and implementation of participatory and pro-poor approaches to natural resource governance in Bangladesh, including harnessing local and traditional knowledge (Alam et al., 2016; Ferdous et al., 2016; Dasgupta et al., 2019), targeting interventions towards landless or land-poor households (Muhammed et al., 2008; Miah et al., 2014; Rahman et al., 2015; Ferdous et al., 2016), and working with local communities to protect and manage resources (Rahman et al., 2015). It was suggested that participatory co-management could help to resolve trade-offs and conflicts between beneficiaries or between different outcomes (Iftekhar and Takama, 2008).

The grey literature describes long-term projects (**Supplementary Table S5**) that aim to build capacity for

community-based management of natural resources, by establishing community organizations and supporting vulnerable people to adopt diversified and sustainable livelihoods (*Socio-Economic Outcomes*). They show how participatory approaches are crucial for engaging and motivating the community to protect and sustainably manage natural resources (DoE, 2015). Adopting a co-management approach for managing ecologically important wetlands and forests during these initiatives was said to trigger a cultural and policy shift for the government of Bangladesh, from a top-down protection approach towards working with local communities to address the underlying drivers of over-exploitation of natural resources (Winrock International, 2018). Although the benefits of these approaches are self-reported by the project implementers, they hold considerable promise for supporting livelihoods and empowering the vulnerable while protecting critically endangered habitats and species. However, the study methods and outcomes were not always clearly reported.

We found one example of an approach that was implemented without sufficient participation. Attempts to train landless indigenous people to establish contour hedgerows to help them cultivate degraded forest land in the Chittagong Hill Tracts failed, because they found the system too complex and labor-intensive, it used unfamiliar hedgerow species and did not leave enough available land to meet their needs for subsistence cereal crops (Nath et al., 2005). International guidance has now been developed to help define best practice for participatory NbS (IUCN, 2020), including standard reporting criteria, which should help to improve future outcomes.

Governance

A common theme in the literature is that poor governance and corruption frequently undermines the effectiveness of interventions (Iftekhar and Takama, 2008; Abdullah-Al-Mamun et al., 2017). For example, a participatory forestry initiative in Tangail Forest Division showed a bias towards allocating land to local elites who had illegally encroached into forest areas, rather than landless people as intended, due to corruption of forest officials (Muhammed et al., 2008). Rahman et al. (2015) recommend stricter implementation of operational rules, strengthening of institutions for regular monitoring, and increased authority to implement sanctions against violators, to enhance the outcomes of roadside social forestry.

The cost of corruption has been estimated in a study of the Chittagong Hill Tracts, where smallholders must bribe local forestry officials in order to get a license to sell timber from agroforestry, as well as paying bribes at all the checkpoints established to (in theory) control illegal felling. Without paying the bribes of Taka 150 per cubic foot of timber, roughly 20% of the market price, the profitability of agroforestry would double. Setting up local collectives would enable smallholders to get a fairer price for agroforestry products by weakening the market dominance of large traders and middlemen (Rasul and Thapa, 2007). Strong, transparent and fair institutions that focus on empowering the vulnerable can ensure that the benefits of NbS flow to those most in need.

Finance, Land Tenure, Training, and Other Support

Although NbS can offer more cost-effective solutions than alternatives in the long term, when all public and private costs and benefits have been taken into account, governments and other funding agencies may need to provide practical and financial support to enable the transition to NbS in a way that meets local needs. For example, farmer training and knowledge of pests and beneficial insects is crucial to application of integrated pest management (Alam et al., 2016), and farmers on the plains of north-west Bangladesh were more likely to adopt conservation tillage if they had access to an agricultural extension office to provide unbiased advice and training (Aravindakshan et al., 2015).

Similarly, in the Chittagong Hills, subsistence farmers who could benefit from agroforestry to stabilize and regenerate the eroding soil (**Section 3.3.3**) face short term barriers including a high cost of borrowing, small size of land holdings, and pressure to produce sufficient crops to feed their families. Agroforestry does not produce economic returns for the first 5 years for fruit, or 10–12 years for timber, while shifting 'jhum' agriculture produces crops in just a few months (Rasul and Thapa, 2006; Rasul, 2009). Also, most farmers do not have secure land tenure, as the forests were nationalized during colonial times, and this discourages long term investments and prevents access to credit for covering initial costs. As a result, farmers continue to practice slash-and-burn cultivation on common land, avoiding the costs of nutrient depletion and soil erosion in the short term by shifting to new locations, but undermining their livelihoods in the long term. This implies that governments and other funding agencies need to enable a shift to more sustainable farming practices by providing financial incentives (such as Payment for Ecosystem Services), access to credit, secure land tenure or inheritable land use rights, and practical training and support (Rasul and Thapa, 2006; Rasul, 2009).

DISCUSSION

Evidence on the Effectiveness of Nature-based Solutions for Addressing Societal Challenges in Bangladesh

A wide range of NbS are being implemented in Bangladesh, including protection and restoration of forests, mangroves, and wetlands; conservation agriculture; agro-forestry; and participatory forest, fishery, and wetland management. We found robust evidence on the benefits of these activities for reducing vulnerability to cyclones, storm surges, floods, landslides, and salinization, and helping communities adapt to sea level rise, water shortages, high temperatures and extreme rainfall. Carefully designed and managed NbS can sustain livelihoods and reduce poverty and social inequality, by ensuring that the benefits flow to poor, landless and disadvantaged members of the community. In summary, we found examples of how NbS can address climate change and natural hazards while contributing to almost all the Sustainable Development Goals (**Supplementary Table S7**).

NbS must support or preferably enhance biodiversity (Seddon, Smith et al., 2021), and this could help address degradation of

natural habitats in Bangladesh (Bardhan et al., 2012), enhancing the delivery of ecosystem services. For example, we found evidence that species diversity is linked to greater resilience of mangroves to pests and diseases (Dasgupta et al., 2019), greater soil carbon sequestration (Islam et al., 2011) and improved opportunities for eco-tourism (IUCN Bangladesh, 2016). However, most studies did not report evidence of biodiversity benefits, and those that did were largely confined to reports of species richness for a limited number of taxa (mainly birds). In some cases, it was not clear whether biodiversity benefits had been achieved – such as for social forestry plantations that used mainly fast-growing non-native timber species (Rahman et al., 2015). To determine whether biodiversity benefits arise, it is important to report on the baseline or counterfactual scenario, i.e., the previous use of the land, and the likely future use in the absence of the NbS. Ideally, there would be a survey of biodiversity before and after NbS implementation, covering the abundance and richness of multiple taxa such as birds, mammals, reptiles, invertebrates, amphibians, higher and lower plants, and fungi, or, if this is too costly, at least a basic survey to identify the presence or absence of species of conservation concern.

There are gaps in the evidence base in Bangladesh for certain types of NbS, including urban green infrastructure. Evidence from other low to middle income countries could be useful to assess the relevance of these solutions in Bangladesh. In addition, data from other countries with similar ecosystems can help to refine and validate the results of the search for Bangladesh. For example, studies in Florida and New Zealand suggest that the primary benefit of mangroves for coastal flood protection may be in reducing the velocity rather than the height of storm surges (Krauss et al., 2009; Montgomery et al., 2018). However, Bangladesh also provides useful evidence which could be relevant to other countries, such as on mangrove and wetland restoration, community-based resource management, homegardens, floating gardens and application of conservation agriculture techniques to rice-based cropping systems.

Despite the strong potential for NbS to deliver multiple benefits, there are also some limitations. For example, NbS alone may not deliver complete protection from coastal and river flooding – in some areas it will be necessary to combine NbS with engineered defenses and effective hazard warning systems. However, because NbS can reduce hazards such as wave height and velocity, the engineered elements of such hybrid approaches may be smaller and cheaper (e.g., lower embankments), and NbS can also strengthen, shelter and protect infrastructure such as levees so that it is cheaper to maintain and less likely to fail (King and Lester, 1995; Thornton et al., 2019).

Although 62% of outcomes reported in the academic evidence were based on strong evidence, many projects were only reported via grey literature such as project reports, which contained only weak evidence on outcomes. The evidence base could be strengthened by using consistent methodologies to monitor and report on the outcomes of NbS over time; gathering robust quantitative or qualitative data that shows the impacts relative to a baseline or counterfactual and takes account of confounding factors; recording synergies and trade-offs between outcomes; clearly describing governance arrangements, the mode of community participation and social distribution of benefits; and recording measurable outcomes for biodiversity.

Strengths and Limitations of the Review

As far as we are aware this is the first systematic review on the effectiveness of NbS for addressing societal challenges in Bangladesh. It shows how the methodology developed for the global review by Chausson, Turner et al. (2020) can be adapted to focus in more detail on a single country and more comprehensively cover additional outcomes including climate change mitigation and development goals.

There are several limitations: we did not cover articles in languages other than English; and we excluded 236 papers at the abstract screening stage that did not refer to evidence on the effectiveness of NbS in the abstract, which could contain relevant evidence in the main text. However, our co-authors in Bangladesh can confirm that almost all projects pertinent to NbS prepare their most important reports in English, since these are funded by various development partners. Other project outputs such as reports on specific activities, guidelines for community-based organizations, case studies and communication materials are usually prepared in the local language (Bangla), but these are not suitable sources of information for our review. In addition, almost all peer-reviewed journal articles are in English.

We covered only studies of NbS interventions in Bangladesh. Studies on similar NbS in other countries could also be useful. For example, Chausson et al., 2020 found 14 papers on mangroves for coastal protection in other countries and 13 papers on NbS in South and South-east Asia, many of which may be relevant to Bangladesh.

Scaling up High Quality Nature-based Solutions in Bangladesh

Our review showed the importance of protecting irreplaceable natural assets such as forests and wetlands in planning policies, and recognizing the non-market benefits they deliver. However, the integration of NbS into policy is currently patchy and inconsistent. For example, a review of key national and sectoral development and climate change policies found that although Ecosystem-based Adaptation (EbA) is considered in most of them, especially at the top strategic level, it is largely ignored at the policy formulation and implementation stage where priority is given to engineered approaches such as concrete dams and embankments (Huq et al., 2017). Only 38 out of 329 climate change adaptation projects reviewed were related to ecosystem interventions and of these 14 were river dredging, and the rest were mainly concerned with commercial forestry, neither of which are NbS as they may have adverse biodiversity impacts. All sectoral development policies except the coastal sector largely ignored the potential for EbA, with climate change adaptation and ecosystem approaches being seen as competing rather than complementing one another. The review concluded that there was an institutional and cultural bias towards hard engineering adaptation options, and lack of awareness of the potential of NbS/EbA amongst policymakers,

compounded by top-down decision-making, bureaucracy, lack of stakeholder engagement and corruption.

However, more recent analyses showed that Bangladesh's policy documents, strategies and plans do involve certain elements and approaches of NbS (Tasnim et al., 2020; Irfanullah 2021a) and that Bangladesh is showing increasing policy interest in NbS (Irfanullah, 2020). Several important, practical suggestions arose from a consultation on NbS for development planning in Bangladesh co-organized by Bangladesh Planning Commission, involving government agencies, researchers and practitioners (ICCCAD, 2020). These included: 1) NbS should be incorporated in Bangladesh's 5-year development plans; 2) use of NbS for mitigation and adaptation to climate change should be included in Bangladesh's Nationally Determined Contributions (NDC) in detail; 3) government's project design guidelines should include NbS so that ecosystem-based approaches are always considered in development projects; 4) a NbS database should be created to encourage a deeper understanding of NbS and aid identification of good practice; 5) opportunities to incorporate NbS in the agriculture sector should be explored, to reduce damage to biodiversity from the food supply chain; and 6) local people should be at the core of NbS planning and implementation.

Similarly, a systematic analysis of twenty policy documents in the development, climate and environment sectors found that although only one used NbS terminology, there was a growing emphasis on the protection and management of natural ecosystems using concepts such as ecosystem-based adaptation, ecosystem services, and green building (Islam et al., 2021). Nevertheless, there was a lack of implementation guidelines, financial support and mechanisms for monitoring and evaluating NbS initiatives, and a need for greater inter-ministry cooperation; national funding support; a national promotional campaign; more evidence-based research and capacity-building; and greater involvement of youth, marginalized people, and women.

Implications and the Way Forward

We have identified many promising NbS initiatives in Bangladesh, but there is potential to achieve much greater benefits by scaling these actions up across the country, and adopting best practice to maximize the benefits and minimize trade-offs. Based on the findings of this review, we identify four priority areas for action on NbS by Bangladesh, which are also likely to be applicable to other low and lower-middle-income countries.

Strengthening the Evidence Base and Integrating It Into Policy

There is an opportunity to capitalize on recent interest in NbS, both globally and in Bangladesh, and to promote evidence-informed policy and practice to influence nature conservation and climate resilience. The evidence that we have compiled on the effectiveness of NbS interventions, such as the creation of coastal green belts with mangroves over the last 56 years, protection of World Heritage and Ramsar Site the Sundarbans, and sustainable management of wetlands over the last 22 years, is a good starting point, but we also recommend strengthening this evidence base through a more systematic approach to monitoring, evaluating,

and reporting the process and outcomes of future NbS projects. Nevertheless, our analysis can help Bangladesh to effectively incorporate nature conservation and ecosystem-based approaches in implementing its current plans in the short-term (e.g., *8th Five-Year Plan 2020–2025*), medium-term (e.g., *Perspective Plan of Bangladesh 2021–2041*), and long-term (e.g., *Bangladesh Delta Plan 2100*). The evidence on NbS effectiveness that we have compiled can also help the country to take pragmatic steps in implementing the NDC and National Adaptation Plan (NAP) (under preparation) as well as any plans developed in response to the *Post-2020 Global Biodiversity Framework* to guide biodiversity conservation through 2050.

Nature-based Solutions for Economic Recovery

As the world is trying to focus on post-pandemic recovery, the International Labour Organization has advocated the potential for NbS to boost economic recovery by increasing green employment opportunities (WWF and ILO, 2020). Under its Nature-based Recovery Initiative, IUCN has been working with its Members and partners to create evidence to support governments to invest at least 10% of overall investments in nature and to ensure that economic investment in the post-COVID era doesn't cause further harm to nature and livelihoods (IUCN, 2021). Bangladesh is in a good position to harness this opportunity, given its long experience of implementing NbS interventions as community-based management of natural resources, community-based adaptation, and co-management of protected areas. The economic recovery potentials of different NbS interventions in a wide range of ecosystems of the country could be investigated and incorporated in the national COVID recovery plans.

Urban Nature-based Solutions

Our world is urbanizing exponentially, and 68% or 7 billion people could live in cities and towns by 2050 (WEF, 2020), yet experience of urban NbS in Bangladesh is relatively limited. Some recent initiatives bring together policies and practices on ecosystem-based approaches in urban areas, such as the Global Commission on Adaptation (www.gca.org), the Network Nature (www.networknature.eu) of the European Union, and the BiodiverCities by 2030 initiative of the World Economic Forum and the Government of Colombia (www.weforum.org). In Bangladesh, with highly vulnerable coastal towns and increasing climate-induced displacements, urban local government institutions and development partners should make NbS an integral part of urban development strategies and plans (Irfanullah, 2021b). NbS interventions in urban settings should restore and manage urban ecosystems and biodiversity, help to address conflicts over natural resources, and ensure social equity within the expanding urban slums. Local institutions and communities should either lead or be appropriately and sufficiently involved in planning, executing, and monitoring NbS in towns and cities.

Nature-based Solutions Guidelines

It is important to understand the scope, effectiveness and limitations of NbS to avoid any miscommunication, misuse and

misinterpretation (Irfanullah, 2021a). Funding and implementing agencies and other stakeholders should abide by the available standards and guidelines when designing, implementing, and scaling up NbS initiatives. The *IUCN Global Standard for NbS* (IUCN, 2020) brings together experience from 100 countries. It guides stakeholders to co-define societal challenges so that they can co-design suitable NbS at an appropriate scale, and checks that NbS are economically feasible, provide sufficient biodiversity and human well-being benefits, involve all stakeholders equitably, and manage trade-offs. Similarly, Seddon et al. (2021) urge stakeholders to follow four guiding principles: NbS are not a replacement for the rapid decarbonization of the economy; they should involve a range of terrestrial, freshwater and marine ecosystems; they are designed, implemented, managed and monitored by or in partnership with Indigenous peoples and local communities; and they should provide measurable benefits for biodiversity.

CONCLUSION

We have found that a range of NbS are already being implemented in Bangladesh, and these are helping to address interlinked societal challenges including disaster risk reduction, climate change adaptation and mitigation, biodiversity loss and other sustainable development goals. There is robust evidence that protecting and restoring forests and mangroves helps to protect communities and property from cyclones, floods and landslides. Together with conservation agriculture, agro-forestry, and participatory fishery and wetland management, these NbS help communities to reduce their vulnerability to the impacts of climate change such as sea level rise, water shortages, high temperatures and extreme rainfall. Understanding the benefits of NbS can help to make the case for protecting Bangladesh's remaining high value natural assets, including the Sundarbans mangroves and Chittagong hill forests, as well as implementing more sustainable agricultural practices such as agro-ecology and agroforestry in the farmed landscape. Carefully designed and well-governed NbS can also help to deliver development benefits by sustaining livelihoods, boosting local economies, strengthening institutions, and reducing poverty and social inequality. In summary, NbS support an integrated approach to delivering multiple Sustainable Development Goals and provide the foundation for a Green Recovery from the COVID-19 pandemic.

However, NbS need to be implemented carefully and in line with good practice guidelines in order to manage trade-offs and secure multiple long-term dividends for both nature and people. Key enabling factors are a participatory approach that incorporates local and traditional knowledge; strong and transparent governance and community institutions; and a focus on empowering the vulnerable and equitably distributing the benefits to those most in need. Attention is also needed to ensure that NbS deliver genuine benefits for biodiversity, thus helping to sustain resilient ecosystems which can underpin health and prosperity in the long term.

The review revealed an evidence gap on urban green infrastructure, a lack of strong evidence on biodiversity outcomes, and inadequate reporting of participatory engagement and governance arrangements. In view of the rapid pace of urbanization, we recommend more attention on the potential for urban NbS such as sustainable drainage systems, green roofs and walls, parks and street trees to help with managing flooding and heatwaves while supporting health and wellbeing in cities. In general, we recommend a more systematic approach to gathering and reporting evidence on the process and outcomes of NbS projects in order to build the evidence base and maximize opportunities to learn about what works in different contexts.

This review can support evidence-based deployment of well-designed NbS in relevant government policy in Bangladesh, including plans for climate change adaptation, mitigation, sustainable development, and biodiversity. NbS are context-specific, but many of the lessons learnt in Bangladesh are more widely applicable. By building on the experience and lessons learnt from deployment of NbS over the last few decades, Bangladesh is well placed to lead the way in showing how other countries and communities around the world can protect and enhance their natural assets in order to address multiple societal challenges sustainably.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

AS and TT performed the systematic review and analysis, AS, TT and HI wrote the paper, NS, BT and AC developed the methodology for the systematic review and contributed to the paper.

FUNDING

ACKNOWLEDGMENTS

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.737659/full#supplementary-material

REFERENCES

Abdullah-Al-Mamun, M. M., Masum, K. M., Raihan Sarker, A. H. M., and Mansor, A. (2017). Ecosystem Services Assessment Using a Valuation Framework for the Bangladesh Sundarbans: Livelihood Contribution and Degradation Analysis. *J. For. Res.* 28 (1), 1–13. doi:10.1007/s11676-016-0275-5

Ahammad, R., Nandy, P., and Husnain, P. (2013). Unlocking Ecosystem Based Adaptation Opportunities in Coastal Bangladesh. *J. Coast Conserv.* 17 (4), 833–840. doi:10.1007/s11852-013-0284-x

Akber, M. A., Patwary, M. M., Islam, M. A., and Rahman, M. R. (2018). Storm Protection Service of the Sundarbans Mangrove Forest, Bangladesh. *Nat. Hazards.* 94 (1), 405–418. doi:10.1007/s11069-018-3395-8

Akhter, M. F., and Uddin, M. S. (2010). Bioremediation of Arsenic in Some Selected Agricultural Crops in bangladesh. *Sustainability Matters.* 1–0, 491–514. doi:10.1142/9789814322911_0020

Alam, M. K., Bell, R. W., and Biswas, W. K. (2019). Increases in Soil Sequestered Carbon Under Conservation Agriculture Cropping Decrease the Estimated Greenhouse Gas Emissions of Wetland Rice Using Life Cycle Assessment. *J. Clean. Prod.* 224, 72–87. doi:10.1016/j.jclepro.2019.03.215

Alam, M. K., Bell, R. W., Haque, M. E., Islam, M. A., and Kader, M. A. (2020). Soil Nitrogen Storage and Availability to Crops Are Increased by Conservation Agriculture Practices in Rice-Based Cropping Systems in the Eastern Gangetic Plains. *Field Crops Res.* 250, 107764. doi:10.1016/j.fcr.2020.107764

Alam, M. K., Salahin, N., Islam, S., Begum, R. A., Hasanuzzaman, M., Islam, M. S., et al. (2017). Patterns of Change in Soil Organic Matter, Physical Properties and Crop Productivity Under Tillage Practices and Cropping Systems in Bangladesh. *J. Agric. Sci.* 155 (2), 216–238. doi:10.1017/S0021859616000265

Alam, M. Z., Crump, A. R., Haque, M. M., Islam, M. S., Hossain, E., Hasan, S. B., et al. (2016). Effects of Integrated Pest Management on Pest Damage and Yield Components in a Rice Agro-Ecosystem in the Barisal Region of Bangladesh. *Front. Environ. Sci.* 4, 22. doi:10.3389/fenvs.2016.00022

Aravindakshan, S., Rossi, F. J., and Krupnik, T. J. (2015). What Does Benchmarking of Wheat Farmers Practicing Conservation Tillage in the Eastern Indo-Gangetic Plains Tell Us about Energy Use Efficiency? an Application of Slack-Based Data Envelopment Analysis. *Energy.* 90, 483–493. doi:10.1016/j.energy.2015.07.088

Bardhan, S., Jose, S., Biswas, S., Kabir, K., and Rogers, W. (2012). Homegarden Agroforestry Systems: An Intermediary for Biodiversity Conservation in Bangladesh. *Agroforest Syst.* 85 (1), 29–34. doi:10.1007/s10457-012-9515-7

Baudron, F., Tomscha, S. A., Powell, B., Groot, J. C. J., Gergel, S. E., and Sunderland, T. (2019). Testing the Various Pathways Linking Forest Cover to Dietary Diversity in Tropical Landscapes. *Front. Sustain. Food Syst.* 3, 97. doi:10.3389/fsufs.2019.00097

Begum, K., Kuhnert, M., Yeluripati, J., Ogle, S., Parton, W., Kader, M. A., et al. (2018). Soil Organic Carbon Sequestration and Mitigation Potential in a rice Cropland in Bangladesh - a Modelling Approach. *Field Crops Res.* 226, 16–27. doi:10.1016/j.fcr.2018.07.001

Bell, R., Haque, M., Jahiruddin, M., Rahman, M., Begum, M., Miah, M., et al. (2019). Conservation Agriculture for Rice-Based Intensive Cropping by Smallholders in the Eastern Gangetic Plain. *Agriculture* 9 (1), 5. doi:10.3390/agriculture9010005

Chausson, A., Turner, C. B., Seddon, D., Chabaneix, N., Girardin, C. A. J., Key, I., et al. (2020). Mapping the Effectiveness of Nature-Based Solutions for Climate Change Adaptation. *Glob. Change Biol.* 26 (11), 6134–6155. doi:10.1111/gcb.15310

Chen, C., Noble, I., Hellmann, J., Coffee, J., Murillo, M., and Chawla, N. (2015). *University of Notre Dame Global Adaptation index Country index Technical Report.* USA: ND-GAIN: South Bend.

Chow, J. (2018). Mangrove Management for Climate Change Adaptation and Sustainable Development in Coastal Zones. *J. Sustainable For.* 37 (2), 139–156. doi:10.1080/10549811.2017.1339615

Chowdhury, M. S. N., Walles, B., Sharifuzzaman, S., Shahadat Hossain, M., Ysebaert, T., and Smaal, A. C. (2019). Oyster Breakwater Reefs Promote Adjacent Mudflat Stability and Salt Marsh Growth in a Monsoon Dominated Subtropical Coast. *Sci. Rep.* 9 (1), 8549. doi:10.1038/s41598-019-44925-6

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., et al. (2019). Core Principles for Successfully Implementing and Upscaling Nature-Based Solutions. *Environ. Sci. Pol.* 98, 20–29. Scopus. doi:10.1016/j.envsci.2019.04.014

Das, S. C., Tanaka, N., and Iimura, K. (2010). "Effects of Coastal Vegetation Species and Ground Slope on Storm Surge Disaster Mitigation," in Proceedings of the Coastal Engineering Conference. Available at: https://jglobal.jst.go.jp/en/detail?JGLOBAL_ID=201902219790697317.

Dasgupta, S., Islam, M. S., Huq, M., Huque Khan, Z., and Hasib, M. R. (2019). Quantifying the Protective Capacity of Mangroves From Storm Surges in Coastal Bangladesh. *PLoS One.* 14 (3), e0214079. doi:10.1371/journal.pone.0214079

DoE (2015). *Community Based Ecosystem Conservation and Adaptation in Ecologically Critical Areas of Bangladesh: Responding to Nature and Changing Climate.* Dhaka: Department of Environment DoE. Ministry of Environment and Forests, Government of the People's Republic of Bangladesh. Available at: https://portals.iucn.org/library/node/45957.

Eckstein, D., Winges, M., Künzel, V., and Schäfer, L. (2019). *Global Climate Risk Index 2020 Who Suffers Most from Extreme Weather Events? Wether-Related Loss Events in 2018 and 1999 to 2018.* GermanWatch e.V., Bonn.

FAOSTAT (2018). *Land Use Data.* Rome, Italy: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/faostat/en/#data/RL (Accessed March 6, 2021).

Ferdous, Z., Datta, A., Anal, A. K., Anwar, M., and Khan, A. S. M. M. R. (2016). Development of home Garden Model for Year Round Production and Consumption for Improving Resource-Poor Household Food Security in Bangladesh. *NJAS: Wageningen J. Life Sci.* 78, 103–110. doi:10.1016/j.njas.2016.05.006

Gafur, A., Jensen, J. R., Borggaard, O. K., and Petersen, L. (2003). Runoff and Losses of Soil and Nutrients From Small Watersheds Under Shifting Cultivation (Jhum) in the Chittagong Hill Tracts of Bangladesh. *J. Hydrol.* 279 (1), 293–309. doi:10.1016/S0022-1694(03)00263-4

Gathala, M. K., Timsina, J., Islam, M. S., Krupnik, T. J., Bose, T. R., Islam, N., et al. (2016). Productivity, Profitability, and Energetics: A Multi-Criteria Assessment of Farmers' Tillage and Crop Establishment Options for Maize in Intensively Cultivated Environments of South Asia. *Field Crops Res.* 186, 32–46. doi:10.1016/j.fcr.2015.11.008

Hanif, M. A., Bari, M. S., and Rahman, A. (2015). Potentiality of Carbon Sequestration by Agroforestry Species in Bangladesh. *Rese. Crop.* 16, 562–567. doi:10.5958/2348-7542.2015.00080.7

Hoque, M. A.-A., Ahmed, N., Pradhan, B., and Roy, S. (2019). Assessment of Coastal Vulnerability to Multi-Hazardous Events Using Geospatial Techniques along the Eastern Coast of Bangladesh. *Ocean Coastal Management.* 181, 104898. doi:10.1016/j.ocecoaman.2019.104898

Hoque, M. Z., Cui, S., Islam, I., Xu, L., and Tang, J. (2020). Future Impact of Land Use/Land Cover Changes on Ecosystem Services in the Lower Meghna River Estuary, Bangladesh. *Sustainability.* 12 (5), 2112. doi:10.3390/su12052112

Huq, N., Bruns, A., Ribbe, L., and Huq, S. (2017). Mainstreaming Ecosystem Services Based Climate Change Adaptation (EbA) in Bangladesh: Status, Challenges and Opportunities. *Sustainability.* 9 (6), 926. doi:10.3390/su9060926

ICCCAD (2020). *Nature-Based Solutions for Development Planning in Bangladesh. Learning Hub Event Report, Bangladesh Planning Commission and International Centre for Climate Change and Development (ICCCAD),* Dhaka, Bangladesh. Available at: https://www.naturebasedsolutionsinitiative.org/wp-content/uploads/2020/04/20200329_FinalReport_LHE_NBS_version01-1.pdf.

Iftekhar, M. S., and Takama, T. (2008). Perceptions of Biodiversity, Environmental Services, and Conservation of Planted Mangroves: A Case Study on Nijhum Dwip Island, Bangladesh. *Wetlands Ecol. Manage.* 16 (2), 119–137. doi:10.1007/s11273-007-9060-8

Imam, M. A., Haque, M. Z., and Yunus, S. (2016). Scarcity to Solution: Perceived Reasons for Safe Drinking Water Scarcity and Local Coping Responses in a Coastal Village of Bangladesh. *J. Water Clim. Change.* 7 (3), 542–550. doi:10.2166/wcc.2016.090

Irfanullah, H. M., Adrika, A., Ghani, A., Khan, Z. A., and Rashid, M. A. (2008). Introduction of Floating Gardening in the North-Eastern Wetlands of Bangladesh for Nutritional Security and Sustainable Livelihood. *Renew. Agric. Food Syst.* 23 (2), 89–96. doi:10.1017/S1742170507002074

Irfanullah, H. Md. (2020). 2020 Has Been a Year of Nature-Based Solutions. So what Awaits Us in 2021? The Daily Star. Available at: https://www.thedailystar.net/opinion/news/2020-has-been-year-nature-based-solutions-2016377.

Irfanullah, H. Md. (2021a). Capitalising on Nature-Based Solutions. *Crisis Response J.* 16 (2), 26–27.

Irfanullah, H. Md. (2021b). Nature-Based Solutions for Our Towns and Cities. The Daily Star. Available at: https://www.thedailystar.net/opinion/news/nature-based-solutions-our-towns-and-cities-2064473.

Islam, M., Dey, A., and Rahman, M. (2015). Effect of Tree Diversity on Soil Organic Carbon Content in the Homegarden Agroforestry System of North-Eastern Bangladesh. *Small-Scale For.* 14 (1), 91–101. doi:10.1007/s11842-014-9275-5

Islam, M. M., Karim, A., Jahiruddin, M., Majid, N. M., Miah, M. G., Ahmed, M. M., et al. (2011). Effects of Organic Manure and Chemical Fertilizers on Crops in the Radish-Stem Amaranth- Indian Spinach Cropping Pattern in homestead Area. Available at: Undefined./paper/Effects-of-organic-manure-and-chemical-fertilizers-Islam-Karim/864f545ed061a65c679acdd5d0fc1f2544747368.

Islam, S., Anzum, F., Kamal, A. B., Akter, M., Rezaie, A. M., and Khan, M. R. (2021). The Integration of Nature-Based Solutions into Climate Adaptation Policy and Planning in Bangladesh. *Jspg.* 18 (02). doi:10.38126/JSPG180204

Islam, S., Gathala, M. K., Tiwari, T. P., Timsina, J., Laing, A. M., Maharjan, S., et al. (2019). Conservation Agriculture Based Sustainable Intensification: Increasing Yields and Water Productivity for Smallholders of the Eastern Gangetic Plains. *Field Crops Res.* 238, 1–17. doi:10.1016/j.fcr.2019.04.005

Islam, S., and Rahman, A. (2019). *Slope Stability Problem and Bio-Engineering Approach on Slope Protection.* Bangladesh: Case Study of Cox's Bazar Area.

IUCN Bangladesh (2016). *Tanguar Haor: A Decade-Long Conservation Journey.* Dhaka: IUCN Bangladesh Country Office. Available at: https://www.researchgate.net/publication/337945961_Tanguar_Haor_A_Decade-long_Conservation_Journey_2016.

IUCN (2020). *Guidance for Using the IUCN Global Standard for Nature-Based Solutions. A User-Friendly Framework for the Verification, Design and Scaling up of Nature-Based Solutions.* Gland, Switzerland: IUCN, 62. Available at: https://portals.iucn.org/library/sites/library/files/documents/2020-021-En.pdf.

IUCN (2021). Nature-Based Recovery Initiative. IUCN, International Union for Conservation of Nature. Available at: https://www.iucn.org/about/senior-management/director-general/nature-based-recovery-initiative (Accessed October 5, 2021).

Kabir, H., Kibria, M., Jashimuddin, M., and Hossain, M. M. (2015). Conservation of a River for Biodiversity and Ecosystem Services: the Case of the Halda - the Unique River of Chittagong, Bangladesh. *Int. J. River Basin.* 13 (3), 333–342. doi:10.1080/15715124.2015.1012514

King, S. E., and Lester, J. N. (1995). The Value of Salt Marsh as a Sea Defence. *Mar. Pollut. Bull.* 30, 180–189. doi:10.1016/0025-326x(94)00173-7

Kossin, J. P., Knapp, K. R., Olander, T. L., and Velden, C. S. (2020). Global Increase in Major Tropical Cyclone Exceedance Probability Over the Past Four Decades. *Proc. Natl. Acad. Sci. USA.* 117 (22), 11975–11980. doi:10.1073/pnas.1920849117

Krauss, K. W., Doyle, T. W., Doyle, T. J., Swarzenski, C. M., From, A. S., Day, R. H., et al. (2009). Water Level Observations in Mangrove Swamps During Two Hurricanes in Florida. *Wetlands.* 29, 142–149. doi:10.1672/07-232.1

MACH (2007a). *Completion Report Volume-1. MACH Achievement.* CARITAS Bangladesh: Winrock International, Bangladesh Centre for Advanced Studies, Center for Natural Resource Studies. Available at: http://nishorgo.org/wp-content/uploads/2017/04/2-1-1-Completion-Report-Vol-1.pdf.

MACH-II (2007b). *Completion Report Volume-2.* CARITAS Bangladesh: MACH Performance Monitoring. Winrock International, Bangladesh Centre for Advanced Studies, Center for Natural Resource Studies. Available at: http://nishorgo.org/wp-content/uploads/2017/04/2-1-2-Completion-Report-Vol-2.pdf.

Menéndez, P., Losada, I. J., Torres-Ortega, S., Narayan, S., and Beck, M. W. (2020). The Global Flood Protection Benefits of Mangroves. *Sci. Rep.* 10 (1), 4404. doi:10.1038/s41598-020-61136-6

Miah, D., Abubokor Siddik, M., and Yong Shin, M. (2013). Socio-Economic and Environmental Impacts of Casuarina Shelterbelt in the Chittagong Coast of Bangladesh. *For. Sci. Technology.* 9 (3), 156–163. doi:10.1080/21580103.2013.814592

Miah, G., Bari, N., and Rahman, A. (2010). Resource Degradation and Livelihood in the Coastal Region of Bangladesh. *Front. Earth Sci. China.* 4 (4), 427–437. doi:10.1007/s11707-010-0126-1

Miah, M. D., Akther, S., Shin, M. Y., and Koike, M. (2014). Scaling up REDD+ Strategies in Bangladesh: A forest Dependence Study in the Chittagong Hill Tracts. *For. Sci. Technology.* 10 (3), 148–156. doi:10.1080/21580103.2014.889045

MoEFCC (2021). *Nationally Determined Contributions (NDCs) 2021.* (updated). Bangladesh: Ministry of Environment, Forest and Climate Change, Government of the People's Republic of Bangladesh. Available at: https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Bangladesh%20First/NDC_submission_20210826revised.pdf.

Mohammed, A. J., Inoue, M., Peras, R. J., Nath, T. K., Jashimuddin, M., and Pulhin, J. M. (2016). Transformation Strategy for Managing Coupled Socio-Ecological Systems: Case Studies from Bangladesh and the Philippines. *Small-Scale For.* 15 (2), 213–227. doi:10.1007/s11842-015-9318-6

Montgomery, J., Bryan, K., Horstman, E., and Mullarney, J. (2018). Attenuation of Tides and Surges by Mangroves: Contrasting Case Studies From New Zealand. *Water.* 10, 1119. doi:10.3390/w10091119

Moser, S. C., and Ekstrom, J. A. (2010). A Framework to Diagnose Barriers to Climate Change Adaptation. *Proc. Natl. Acad. Sci.* 107 (51), 22026–22031. doi:10.1073/pnas.1007887107

Muhammed, N., Koike, M., Haque, F., and Miah, M. D. (2008). Quantitative Assessment of People-Oriented Forestry in Bangladesh: A Case Study in the Tangail forest Division. *J. Environ. Manage.* 88 (1), 83–92. doi:10.1016/j.jenvman.2007.01.029

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., van Wesenbeeck, B., Pontee, N., et al. (2016). The Effectiveness, Costs and Coastal Protection Benefits of Natural and Nature-Based Defences. *PLoS One.* 11 (5), e0154735. doi:10.1371/journal.pone.0154735

Nath, T. K., Aziz, N., and Inoue, M. (2015). Contribution of Homestead Forests to Rural Economy and Climate Change Mitigation: A Study From the Ecologically Critical Area of Cox's Bazar-Teknaf Peninsula, Bangladesh. *Small-Scale For.* 14 (1), 1–18. doi:10.1007/s11842-014-9270-x

Nath, T. K., Inoue, M., and Myant, H. (2005). Small-Scale Agroforestry for Upland Community Development: A Case Study from Chittagong Hill Tracts, Bangladesh. *J. For. Res.* 10 (6), 443–452. doi:10.1007/s10310-005-0171-x

NbSI (2020). *Nature-based Solutions to Climate Change: Key messages for decision makers in 2021 and beyond.* Available at: https://nbsguidelines.info/.

Prabhakar, S. V. R. K. (2021). A Succinct Review and Analysis of Drivers and Impacts of Agricultural Land Transformations in Asia. *Land Use Policy.* 102, 105238. doi:10.1016/j.landusepol.2020.105238

Rahaman, M. F., Jahan, C. S., and Mazumder, Q. H. (2019). Rainwater Harvesting: Practiced Potential for Integrated Water Resource Management in Drought-Prone Barind Tract, Bangladesh. *Groundwater Sustainable Development.* 9, 100267. doi:10.1016/j.gsd.2019.100267

Rahman, M. M., Jiang, Y., and Irvine, K. (2018). Assessing Wetland Services for Improved Development Decision-Making: A Case Study of Mangroves in Coastal Bangladesh. *Wetlands Ecol. Manage.* 26 (4), 563–580. doi:10.1007/s11273-018-9592-0

Rahman, M. M., Kabir, M. E., and Ahmed, I. (2017). "Protected Areas for Climate Change Mitigation and Livelihood Option: A Case Study of the Bangladesh Sundarbans Mangrove Forest," in *Participatory Mangrove Management in a Changing Climate: Perspectives from the Asia-Pacific.* Editors R. DasGupta and R. Shaw (Springer Japan), 119–136. doi:10.1007/978-4-431-56481-2_8

Rahman, M. M., Kabir, M. E., Jahir Uddin Akon, A. S. M., and Ando, K. (2015). High Carbon Stocks in Roadside Plantations Under Participatory Management in Bangladesh. *Glob. Ecol. Conservation.* 3, 412–423. doi:10.1016/j.gecco.2015.01.011

Rahman, S., Islam, M. S., Khan, M. N. H., and Touhiduzzaman, M. (2019). Climate Change Adaptation and Disaster Risk Reduction (DRR) through Coastal Afforestation in South-Central Coast of Bangladesh. *Meq.* 30 (3), 498–517. doi:10.1108/MEQ-01-2018-0021

Rashid, M. H., Timsina, J., Islam, N., and Islam, S. (2019). Tillage and Residue-Management Effects on Productivity, Profitability and Soil Properties in a Rice-Maize-Mungbean System in the Eastern Gangetic Plains. *J. Crop Improvement.* 33 (5), 683–710. doi:10.1080/15427528.2019.1661056

Rasul, G. (2009). Ecosystem Services and Agricultural Land-Use Practices: A Case Study of the Chittagong Hill Tracts of Bangladesh. *Sustainability: Sci. Pract. Pol.* 5 (2), 15–27. doi:10.1080/15487733.2009.11908032

Rasul, G., and Thapa, G. B. (2006). Financial and Economic Suitability of Agroforestry as an Alternative to Shifting Cultivation: The Case of the Chittagong Hill Tracts, Bangladesh. *Agric. Syst.* 91 (1), 29–50. doi:10.1016/j.agsy.2006.01.006

Rasul, G., and Thapa, G. B. (2004). Sustainability of Ecological and Conventional Agricultural Systems in Bangladesh: An Assessment Based on Environmental, Economic and Social Perspectives. *Agric. Syst.* 79 (3), 327–351. doi:10.1016/S0308-521X(03)00090-8

Rasul, G., and Thapa, G. B. (2007). The Impact of Policy and Institutional Environment on Costs and Benefits of Sustainable Agricultural Land Uses: The Case of the Chittagong Hill Tracts, Bangladesh. *Environ. Manage.* 40 (2), 272–283. doi:10.1007/s00267-005-0083-8

Reid, H., and Alam, S. S. (2017). Ecosystem-based approaches to adaptation: Evidence from two sites in Bangladesh. *Clim. Develop.* 9 (6), 518–536. doi:10.1080/17565529.2016.1167663

Reguero, B. G., Beck, M. W., Bresch, D. N., Calil, J., and Meliane, I. (2018). Comparing the Cost Effectiveness of Nature-Based and Coastal Adaptation: A Case Study from the Gulf Coast of the United States. *PLOS ONE.* 13 (4), e0192132. doi:10.1371/journal.pone.0192132

Richards, M., and Hussain, Z. (2019). Final Evaluation of Bangladesh UN-REDD National Programme: Final Draft. UN-REDD. Available at: https://www.unredd.net/documents/un-redd-partner-countries-181/asia-the-pacific-333/a-p-partner-countries/bangladesh-712/national-programme-submission-and-approval-1524/national-programme-documents-2040/17408-un-redd-bangladesh-national-programme-final-evaluation-report-april-2018.html

Roe, D., Turner, C., Chausson, A., Hemmerle, E., and Seddon, N. (2021). *Investing in Nature for Development: Do Nature-Based Interventions Deliver Local Development Outcomes?* London: IIED.

Sayed, A., Sarker, A., Kim, J.-E., Rahman, M., and Mahmud, M. G. A. (2020). Environmental Sustainability and Water Productivity on Conservation Tillage of Irrigated Maize in Red Brown Terrace Soil of Bangladesh. *J. Saudi Soc. Agric. Sci.* 19 (4), 276–284. doi:10.1016/j.jssas.2019.03.002

Schwindaman, J. P., Castle, J. W., and Rodgers, J. H. (2014). Biogeochemical Process-Based Design and Performance of a Pilot-Scale Constructed Wetland for Arsenic Removal From Simulated Bangladesh Groundwater. *Water Air Soil Pollut.* 225 (6). doi:10.1007/s11270-014-2009-7

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., and Turner, B. (2020). Understanding the Value and Limits of Nature-Based Solutions to Climate Change and Other Global Challenges. *Phil. Trans. R. Soc. B.* 375 (1794), 20190120, 2020 . Scopus. doi:10.1098/rstb.2019.0120

Seddon, N., Sengupta, S., Garcia Espinosa, M., Hauler, I., Herr, D., and Rizvi, A. R. (2019). Nature-based Solutions in Nationally Determined Contributions: Synthesis and Recommendations for Enhancing Climate Ambition and Action by 2020. Available at: https://portals.iucn.org/library/node/48525.

Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., et al. (2021). Getting the Message Right on Nature-Based Solutions to Climate Change. *Glob. Change Biol.* 27 (8), 1518–1546. doi:10.1111/gcb.15513

Shi, P., Yang, X., Xu, W., and Wang, J. a. (2016). Mapping Global Mortality and Affected Population Risks for Multiple Natural Hazards. *Int. J. Disaster Risk Sci.* 7 (1), 54–62. doi:10.1007/s13753-016-0079-4

Spires, M., Shackleton, S., and Cundill, G. (2014). Barriers to Implementing Planned Community-Based Adaptation in Developing Countries: A Systematic Literature Review. *Clim. Development.* 6 (3), 277–287. doi:10.1080/17565529.2014.886995

Taillardat, P., Friess, D. A., and Lupascu, M. (2018). Mangrove Blue Carbon Strategies for Climate Change Mitigation Are Most Effective at the National Scale. *Biol. Lett.* 14 (10), 20180251. doi:10.1098/rsbl.2018.0251

Tasnim, T., Anzum, F., Irfanullah, H. M. d., Seddon, N., and Huq, S. (2020). *A Roadmap for Nature-Based Solutions in Bangladesh: Promises and Challenges. Policy Brief. International Centre for Climate Change and Development (ICCCAD), Bangladesh and Nature-Based Solutions.* UK: Initiative of the University of Oxford, 6. Available at: http://www.nbsbangladesh.info/wp-content/uploads/2020/08/ICCCAD-NBSI-Policy-Brief_NbSRoadmap_August2020.pdf.

Thiault, L., Jupiter, S. D., Johnson, J. E., Cinner, J. E., Jarvis, R. M., Heron, S. F., et al. (2021). Harnessing the Potential of Vulnerability Assessments for Managing Social-Ecological Systems. *Ecol. Soc.* 26 (2), 1. doi:10.5751/ES-12167-260201

Thornton, A., Luisetti, T., Grilli, G., Donovan, D., Phillips, R., and Hawker, J. (2019). *Initial Natural Capital Accounts for the UK marine and Coastal Environment.* London: Defra.

Ware, D., Buckwell, A., Tomlinson, R., Foxwell-Norton, K., and Lazarow, N. (2020). Using Historical Responses to Shoreline Change on Australia's Gold Coast to Estimate Costs of Coastal Adaptation to Sea Level Rise. *Jmse.* 8 (6), 380. doi:10.3390/jmse8060380

Winrock International (2018). *Climate-Resilient Ecosystems and Livelihoods (CREL).* Available at: http://nishorgo.org/wp-content/uploads/2017/02/CREL-Report-2013-2018-FINAL.pdf.

Wicke, B., Smeets, E. M. W., Akanda, R., Stille, L., Singh, R. K., Awan, A. R., et al. (2013). Biomass Production in Agroforestry and Forestry Systems on Salt-Affected Soils in South Asia: Exploration of the GHG Balance and Economic Performance of Three Case Studies. *J. Environ. Manage.* 127, 324–334. doi:10.1016/j.jenvman.2013.05.060

Yong Shin, M., Danesh Miah, M., and Lee, K. H. (2007). Potential Contribution of the Forestry Sector in Bangladesh to Carbon Sequestration. *J. Environ. Manage.* 82 (2), 260–276. doi:10.1016/j.jenvman.2005.12.025

Zahid, A., Afzal Hossain, A. F. M., Hazrat Ali, M., Islam, K., and Abbassi, S. U. (2018). "Monitoring the Coastal Groundwater of Bangladesh," in *Groundwater of South Asia.* Editor A. Mukherjee (Springer), 431–451. doi:10.1007/978-981-10-3889-1_26

Zinia, N. J., and McShane, P. (2018). Significance of Urban Green and Blue Spaces: Identifying and Valuing Provisioning Ecosystem Services in Dhaka City. *Eur. J. Sustainable Development.* 7 (1), 435. doi:10.14207/ejsd.2018.v7n1p435

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.