Regional Assessment of the Status of Ecosystems as Nature-Based Solutions for Climate Action: Underscoring the role of blue carbon ecosystems in Asia and the Pacific

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Disclaimer:

This technical background paper was prepared under the project 'Enhancing investments for equitable and accelerated climate action in the post-COVID-19 recovery', and is based on a draft presented to participants in the "Project Inception Meeting, Assessment of Regional Ecosystems as part of a Nature-based Solutions Approach to Climate Action in Asia and the Pacific," held on Wednesday, 14-15 November 2023 in Johor. The secretariat does not guarantee the accuracy of data contained in this report. The designations employed and the presentation of material on maps in this draft report do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

Sustainable Development Green Action

Executive Summary

In the Asia-Pacific region, there is a significant demand for nature-based solutions. This region has contributed over 30% of all global nature-based credits, equivalent to a total of 85 million tons of carbon dioxide (CO2). However, investments in nature-based solutions here remained restricted, with a predominant focus on terrestrial ecosystems such as forests. In the Asia-Pacific region, coastal ecosystems, specifically mangroves, seagrass, and coral reefs, play a critical role in climate change and environmental policies. However, the integration of blue carbon into the NDCs (Nationally Determined Contributions) of the region's countries presents a series of challenges.

Mangroves' role in nature-based solutions is widely acknowledged across countries. Indonesia, Malaysia, and the Philippines are among the few which have explicitly included "blue carbon" terminology in their policies and established national agencies for blue carbon strategies. Furthermore, the roles of seagrass and coral reefs have not gained much attention. Challenges in integrating blue carbon into the NDCs include data limitations, weak technical capacity, coordination issues, overlapping mandates, ecosystem degradation, and funding constraints. However, as stakeholders grow more aware of blue carbon's importance at international, national, and sub-national levels, opportunities arise.

Blue carbon ecosystems can help to mitigate greenhouse gas (GHG) emissions due to high carbon storage and sequestration potential. Coastal vegetated ecosystems, like mangroves and seagrasses, are vital nurseries for commercial fish and could help remove 300-900 million metric tons of CO2 annually, aiding in climate goals. The loss of 2% of mangroves in the Asia Pacific, could lead to the emission of 230 megatons of CO2 from the stored carbon in mangroves. These ecosystems also provide critical ecosystem services to coastal communities, fisheries, and other resource-dependent sectors. Overlooking blue carbon ecosystems may result in the underestimation of GHG sinks and inaccurate reporting of GHG emissions at the national level.

National strategies for integrating blue carbon into NDCs and climate policies vary across countries. Indonesia, for instance, has been developing a Blue Carbon Strategy Framework under its National Medium-Term Development Plan for 2020-2024, with multiple agencies overseeing its implementation. They are guided by presidential decrees and regulations focusing on ocean and marine resource conservation, involving government bodies, civil society organizations, and the private sector, aiming to restore 1.82 million hectares of mangrove ecosystems by 2045. In Samoa, the NDC is under review to consider blue carbon as a carbon sink, and the country has initiated the Mangrove Ecosystems for Climate Change Adaptation and Livelihoods program. Meanwhile, Bangladesh, though not using the term 'blue carbon' in its NDC, recognizes the role of mangroves in climate action through the Bangladesh Climate Change Strategy and Action Plan. The country has already raised substantial mangrove plantations contributing to carbon sequestration and has declared various coastal protected areas. It is noteworthy that the other coastal ecosystems which are significant contributors to blue carbon might be missing from the NDCs.

In this context, this report assesses the coverage of key coastal ecosystems (mangroves, seagrass, and coral reefs) and their conservation and restoration potential. Seizing these opportunities requires further research, enhanced policy and technical guidance, capacity building, and improved coordination among relevant actors.

Mangroves

- **Mangroves, a prevalent feature in tropical and subtropical coastal areas, covered approximately 147,359 km2 globally in 2020, with the majority (51%) found in the Asia-Pacific.** The Asia-Pacific region has 7.48 million hectares of mangroves, which provide ecosystem services valued at US$1.5 trillion annually. Asia produces 75% of the world's commercial shrimp, making mangrove destruction a major threat to the region's economic output and livelihoods. In Indonesia alone, mangroves are essential to an estimated 893,000 small-scale fishers.

- **Mangrove cover is declining fastest in Asia-Pacific compared to all global regions** and Asia-Pacific recorded a net decline in mangrove cover of 3,338 km2 (63% of the global loss) between 1996 and 2020. The rate of loss has decreased in the past decade. Climate change and other human activities are both driving mangrove loss in the Asia-Pacific region. The primary driver of mangrove loss in the region is the expansion of agriculture into mangrove habitats, followed by a rapid increase in brackish water aquaculture.

- **In the last 25 years, the Asia-Pacific region has been responsible for a substantial global loss of carbon stored in mangrove forests, accounting for 70% of the total.** This amounts to a net loss of 98 Mt of carbon[1]. Indonesia experienced the highest losses, followed by Australia. However, the region also gained mangroves which might store 314 Mt CO2, with Bangladesh in the lead in increasing net carbon storage in its mangrove forests. The contrast between mangrove losses in Indonesia and gains in Bangladesh is likely attributable to the varying degrees of mangrove protection within these countries. In Bangladesh, a significant 88% of mangroves are under protection, whereas in Indonesia, only 25%.

- **A notional mangrove restoration "threshold" of 1350 km2 (135000 hectares) by 2030 is proposed for the Asia-Pacific region.** Mangrove loss is a serious problem in the Asia-Pacific region, but there is also a great deal of potential for restoration. A notional target (or, better, threshold) of restoring 1350 km2 (135000 hectares) of mangrove forest by 2030 has been identified by this study. This would recover 70% of the losses caused by direct human activities in the last ten years and 50% of the previously recoverable losses that occurred over the past 25 years.

[1] C - CO2 Conversion Factor is 3.67 (IPCC, 2007)

- **Such a target also can contribute to advancing existing regional and global restoration targets**,[2] and can store approximately 209 Mt of additional CO2. Furthermore, securing the protection of 40% of existing mangroves in the Asia Pacific region would ensure a storage capacity of 4.65 Gt of CO2 and the commercial fish productivity worth US$143-183 billion annually. Indonesia has the largest potential restoration area in the world, and it is important to develop policies to support mangrove restoration efforts in this region.

- **This notional target for the region is broken down to notional targets for each country**, as a basis for further assessment and stakeholder dialogue within each country. The proposed target should be considered a threshold for mangrove restoration; it may be far below a given country's ambitions or may exceed current provisions and plans for protection and restoration. The reference to the proportion of "restorable" mangrove cover contributes to the discussion already under way in many countries.

Coral reefs

- **The Asia-Pacific region alone supports over 77% of the world's coral reefs in 2019.** The annual value of these ecosystem services is assessed at an astounding US$7.1 trillion. Coral reefs cover less than 0.2% of the global ocean floor, but they are one of the most diverse ecosystems on Earth, providing a habitat for about 25% of all known marine species. The Asia-Pacific region plays a pivotal role in hosting and preserving most of the world's coral reefs, contributing substantially to the immense value of these ecosystems in terms of the ecological, economic, and social support they provide.

- **Coral reefs have faced a significant decline, with a loss of nearly one-quarter of their cover in the last 15 years**. The rate of coral loss accelerated from 3.4% annually in the late 2000s to early 2010s to a staggering 18.7% annually in the early 2010s to late 2010s. Global warming and ocean water acidification pose severe threats to these ecosystems and their ability to store carbon, particularly due to the rise in Sea Surface Temperature (SST), which is the primary driver of widespread coral bleaching. More than half of the world's coral reefs have already vanished, and the projected loss could reach 70-90% if global temperatures increase by 1.5°C.

- **Assessment of the carbon balance of coral reefs is difficult, as ocean acidification slows the rate of accumulation of carbon.** However, they are understood as net carbon sinks that provide an important protective and biodiversity related ecosystem services.

[2] Regional Strategy and Action Plan for Forest and Landscape Restoration in Asia-Pacific (fao.org); The Bonn Challenge; UN Decade on Restoration; 2030 Targets (with Guidance Notes) (cbd.int)

- **Among the various challenges faced by coral reefs due to climate change, the increased frequency and severity of coral bleaching are major concerns.** By 2050, within the RCP 4.5 emission scenario, it is projected that 70% of coral reefs in the Asia Pacific will experience two bleaching events per decade (2X), and at least half of them might face annual bleaching (10X). Under the emission scenario RCP 8.5, the situation could exacerbate, with projections indicating that 93% (2X) and 85% (10X) of reefs are at risk of bleaching.

- **The Asia-Pacific region is anticipated to face significant threats to its coral reefs, with 60% of them projected to be at high (34%), very high (17%), and critical (9%) risk from combined local and global pressures by 2030**. Urgent recovery plans are essential, particularly for the critically and very highly threatened coral reefs in the region. Conserving and restoring these high-risk coral reefs could ensure ecosystem services worth US$4.05 trillion from 11.5 million hectares of coral reefs by 2030 and US$5.14 trillion from 14.6 million hectares by 2050.

- **Southeast Asia boasts the most diverse coral reefs globally, yet they are also the most jeopardised, with over 95% facing threats due to global warming and ocean acidification**. Indonesia holds the largest expanse of threatened coral reefs, primarily driven by fishing pressures. More than 65% of coral reefs in the Indian Ocean are under stress due to local threats, while nearly 50% of coral reefs in the Pacific region are similarly threatened. This adversity has far-reaching consequences, negatively impacting coastal communities and the food security of the area. To safeguard the resilience and well-being of coral reef ecosystems, it is imperative to maintain ongoing monitoring efforts aimed at mitigating local human-induced pressures, land-based and marine pollution, overfishing, and destructive fishing practices, while simultaneously addressing global climate change, including ocean acidification.

Seagrasses

- **The Asia-Pacific region is home to roughly a quarter of the world's seagrass meadows**. These ecosystems, despite covering a small fraction of the ocean floor, store a remarkable 18% of the world's oceanic carbon. They are exceptionally efficient at carbon storage, up to 40 times more so than land-based forests These seagrass meadows also serve as a natural buffer against coastal erosion caused by storms.

- **Seagrass meadows play a crucial role in nature-based solutions for climate change mitigation.** In the Asia-Pacific region, where seagrass spans approximately 14.92 million hectares, these meadows collectively store a remarkable 2.088 Gt carbon (7.67 Gt CO2) and provide ecosystem services valued at approximately US$432 billion annually.

- **Several studies have documented significant losses of seagrass in Oceania and Southeast Asia.** The rate of decline is over 20% in some areas, such as Viet Nam and

the Philippines. Over 60% of tropical seagrass beds in southeast Asia experienced a decline over the past two decades with an average annual reduction of 10.9%, while 20% of the beds expanded at an average annual rate of 8.1%. The driving forces behind these changes were diverse and included various human-induced threats such as coastal development, fisheries, and aquaculture, as well as extreme climate events. Despite hosting incredibly diverse seagrass ecosystems, this region is relatively underexplored.

- **Seagrass beds offer significant carbon storage benefits and can release substantial carbon dioxide when disturbed.** Approximately 0.15 Pg of CO2 is emitted annually from disturbed seagrass ecosystems globally, which is equivalent to 3% of the annual global CO2 emissions from deforestation. Asia and the Pacific emissions from disturbed seagrass ecosystems makes up about half of the global figure. Encouraging carbon credit markets for seagrass preservation is critical, given the diverse services these ecosystems offer, making them integral to climate change mitigation and adaptation. A systematic assessment of ecosystem services and coastal habitats is necessary to guide effective conservation and management efforts in the region.

This assessment focuses on the condition of mangroves, coral reefs, and seagrass in four Asia-Pacific countries, exploring their potential for nature-based solutions and pilot programs in Indonesia, Bangladesh, Maldives, and Samoa. These findings underscore the substantial potential for diverse nature-based solutions in these target countries. The restoration of mangroves can store a total of 153.30 Mt CO2 in Indonesia, 2.09 Mt CO2 in Bangladesh, and 0.01 Mt CO2 in Samoa. Additionally, these restored ecosystems offer valuable services with a net annual worth of 39,647.9 million US$ in Indonesia, 1,148.6 million US$ in Bangladesh, and 3.2 million US$ in Samoa. Investments aimed at preserving threatened coral reefs by 2030 could yield significant annual ecosystem service values of 900 million $US in Indonesia, 41.53 million $US in Maldives, and 11.86 million $US in Samoa. Furthermore, addressing potential losses and degradation in seagrass areas can provide nature-based solutions by storing approximately 224 Mt CO2 in Indonesia, 40 Mt CO2 in Maldives, and 3.6 Mt CO2 in Samoa.

Nevertheless, it is crucial to emphasize the lack of existing literature and assessments concerning the ever-changing nature of blue carbon ecosystems in the regions. This knowledge deficit underscores a significant gap in our understanding of nature-based solutions and the untapped potential for investments related to the pivotal role of these blue carbon ecosystems in the intricate dynamics of carbon sequestration and release within the region. Addressing these gaps is imperative for harnessing the full ecological and climate-regulating potential of these invaluable ecosystems.

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Abbreviations

ADB	Asian Development Bank
APDRN	Asia-Pacific Disaster Resilience Network
BAU	business as usual
COP	Conference of the Parties
CO2	carbon dioxide
Corg	Organic Carbon
EAP	East Asia-Pacific
EbA	ecosystem-based adaptation
EbM	ecosystem-based mitigation
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization of the United Nations
GHG	greenhouse gas
GLOF	glacial lake outburst flood
GMW	Global Mangrove Watch
GNI	gross national income
GT	giga ton
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
IPMG	Indigenous Peoples' Major Group for Sustainable Development
km	kilometre
km2	Square Kilometre
LULC	Land Use Land Cover
LULCC	Land Use Land Cover Change
MEA	Millennium Ecosystem Assessment
MRV	Monitoring, reporting and verification
NbS	Nature-based Solutions
NCS	Natural climate solution
NDCs	Nationally Determined Contributions
NGO	non-governmental organization
Mg	megagram (1 ton
mm	millimetre
Mt	mega ton or million ton
Pg	Peta gram
REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SDG	Sustainable Development Goals
SIDS	small island developing States
Tg	Terra gram

UNEP	United Nations Environment Programme
UNICEF	United Nations International Children’s Emergency Fund
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WRI	World Resources Institute
yr-1	Per year or annual
yr	year

Disclaimer

The products generated through this overall assessment of the status and trends of the key ecosystem indicators in the Asia Pacific region are executed to the best of our capabilities within a very limited timeframe while maximizing the utilization of available data and information. It's important to note that all geographic information is subject to constraints such as scale, resolution, date, and the interpretation of the sources. Please keep in mind that the thematic accuracy may be lower at the national level due to the inherent limitations of global and regional assessments.

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Introduction

Preventing perilous climate change by maintaining global warming at or below 1.5°C requires undertaking substantial efforts to both remove significant amounts of carbon dioxide from the atmosphere and reduce its emissions. According to the recommendations of the Intergovernmental Panel on Climate Change (IPCC), it is estimated that approximately 730 billion tonnes of CO2 (199 billion tonnes of carbon), must be removed from the atmosphere by the end of 2100 (IPCC, 2018). The carbon sequestration functions of land-based ecosystems reached around 30 per cent of the carbon emissions generated through human activity in the last decade and could provide 20 to 30 % of the mitigation required to ensure global warming stays below 1.5^{o}C towards 2050 (IPCC, 2022). Biodiversity, which is the variety of life on earth, is the foundation for human, environmental and socio-economic well-being. Forest ecosystems are the widely known carbon sinks which play a significant role in the global carbon cycle. However, ocean habitats like seagrasses, mangroves, and coral reefs, if well preserved, could sequester carbon at a rate four times higher than terrestrial forests (UNEP, n.d.). Mangroves, seagrass meadows and coral reefs are all coastal ecosystems which are powerful allies against climate change by providing invaluable natural services, including sequestering carbon dioxide, boosting biodiversity, protecting our coasts from rising sea levels and sea surges, and supporting local livelihoods and as drivers of national economies. Therefore, this assessment focuses on trends in status and knowledge of forests, mangroves, seagrasses, coral reefs and associated carbon pools to devise effective and informed policies to preserve these resources and combat the adverse effects of climate change.

In alignment with the recommendations outlined in the IPCC Sixth Assessment Report and a collective call for countries in the Asia-Pacific region to reach their emissions peak by 2025, followed by concerted efforts to reduce emissions to levels as low as 43 % by 2030, 60 % by 2035, and 84 % by 2050 compared to the 2019 baseline, this translates to a reduction in greenhouse gas emissions equivalent to 17.02 GtCO2e by 2030, 11.94 GtCO2e by 2035, and 4.78 GtCO2e by 2050. However, based on the existing commitments in the Nationally Determined Contributions (NDCs), both conditional and unconditional, and assuming full implementation, it is projected that greenhouse gas emissions will still be relatively high, estimated at 26.73 GtCO2e by 2030. Asia and the Pacific account for more than half of global energy consumption, with 85% of regional consumption coming from fossil fuels. Some countries in Asia now have higher emissions per capita than the global average of 4.1 tonnes, with China emitting more per capita than the European Union. The Asia Pacific region contains 30% of the global land mass and more than half of the world's population, including more than 300 million of the world's extremely poor. In the region, a quarter of the population is food insecure. The number of people facing hunger in the region increased by 54 million, from 321.8 million in 2019 to 375.8 million in 2020 (FAO et al., 2023). Additionally, more than 1.1 billion people did not have access to adequate food in 2020, an increase of 150 million from the previous year. These figures are due to pre-existing economic shocks and the lingering impacts of the COVID-19 pandemic. The war in Ukraine is also having a significant impact on global food, energy, and fertilizer prices and supplies, which poses further threats to food security, nutrition, and livelihoods. The increasing food demand along with pollution growth

is causing the expansion of cropland in the region (Tilman et al., 2011), which is projected to continue to grow in the coming decades (Godfray et al., 2010). Despite the massive increase in cropland, per capita cropland has decreased. Global demand for food and agricultural commodities is projected to increase significantly by 2050 (Zabel et al., 2019). The population growth, demand for food, and cropland expansion induce land use land changes (e.g., clearing forests for agricultural use or direct settlements, and urban sprawls). These transformations in land use land cover directly affect the which directly the exchange of greenhouse gases between terrestrial ecosystems and the atmosphere. These change in the ecosystems reduces the sinks of GHG and replacing land use (e.g., agriculture, pasture, and urban areas emission from vehicular emissions and other industrial emissions) can increase the sources of GHG emission. Food systems are responsible for a third of global anthropogenic GHG emissions (Crippa et al., 2023). The region contributes to over 55% of the global greenhouse gas (GHG) emissions, which reaching close to a 26% increase in 2022 from the 2010 levels and growing continuously (ESCAP, n.d.). Increased GHG emissions from agriculture are a key contributor to climate change and account for up to 80% of biodiversity loss (ADB, 2021).The role of land use and land cover change (LULCC) in both emitting and absorbing carbon is substantial within the global carbon budget (Houghton et al., 2012). Between 2000 and 2009, LULCC contributed approximately 12.5% of total anthropogenic carbon emissions (Friedlingstein et al., 2010). From 1990 to 2009, the average global emissions resulting from land use and land cover change (LULCC) were approximately 1.14 ± 0.18 Pg of carbon per year (Pg C yr^{-1}) (Houghton et al., 2012). In addition to its impact on climate through carbon dioxide emissions, LULCC also influences the climate by releasing chemically and radiatively active gases. Furthermore, LULCC affects climate through biophysical mechanisms that alter surface properties, such as surface albedo, surface roughness, and evapotranspiration (Pongratz et al., 2010). Human activities are the main source of greenhouse gases in the atmosphere, mostly from burning fossil fuels. Land use, such as deforestation, is also a major source of greenhouse gases, accounting for 8-20% of global emissions (van der Werf et al., 2009). Terrestrial forests are a well-known source and sink of greenhouse gases, but new evidence shows that coastal ecosystems such as mangroves, and seagrass beds also release greenhouse gases, when these are degraded or converted to other uses. These carbon stocks are known as "blue carbon" (Gordon et al., 2011). The exact amount of carbon stored in blue carbon ecosystems is still being studied, but their loss could contribute significantly to greenhouse gas emissions. Yet, these emissions are often ignored or neglected in climate change mitigation policies (Climate Focus, 2011; Pendleton et al., 2012).

The Intergovernmental Panel on Climate Change (IPCC) has warned that global mean surface temperature by 2100 is likely to increase by 1.4°C to 4.4°C under five different GHG emissions scenarios. The Asia-Pacific region is highly vulnerable to climate change. The region has a diverse geography, with extensive coastlines, many small island countries, and low-lying coastal territories. This makes it susceptible to rising sea levels and extreme weather events. Half of Asia’s population (2.4 billion people) live in low-lying coastal areas that will be at risk from sea level rise, increased storms, and flooding, with coastal ecosystems also at significant risk. Direct diver of change in ecosystem services includes land use land cover changes, species introduction or removal, external inputs (fertilizers use, pest control, and irrigation), climate

change, and other natural drivers (e.g., volcanos, evolution, etc). The indirect driver of changes in the ecosystem includes demographic, economic, sociopolitical, science and technology, cultural and religious. (Duţescu et al., 2019).

Vegetated coastal ecosystems serve as the foundation for coastal fisheries (Saintilan et al., 2023). They have a crucial role in supporting 95% of commercially valuable fish worldwide by serving as essential nursery habitats for juveniles (Jänes et al., 2020). Moreover, these ecosystems are well placed to contribute to CO2 removal in efforts to maintain warming below 2 °C (Saintilan et al., 2023). Blue carbon ecosystems could potentially mitigate annual carbon emissions in the range of 300 to 900 million metric tons of CO2. This accounts for 7-20% of the yearly emissions resulting from global deforestation and forest degradation, even though blue carbon ecosystems only occupy 1-2% of the total forested area. Unlike terrestrial forests, where a larger portion of carbon is in above-ground biomass, coastal habitats predominantly store carbon in the soil, with approximately 95-99% of the total carbon stock for salt marshes and seagrasses, and 50-90% for mangroves. Mangroves stand out as one of the most carbon-rich forms of vegetation, potentially storing an average of around 3,750 metric tons of CO2 equivalent per hectare, with organic-rich soils extending from 0.5 to over 3 meters in depth (Climate Focus, 2011; Donato et al., 2011; van der Werf et al., 2009).

There is a strong demand for nature-based solutions in the Asia-Pacific region. Over 30% (85 million tonnes of nature-based credits) of all nature-based credits issued globally have come from the Asia-Pacific region. Overall, the investment in nature-based solutions in the Asia Pacific is limited and focused on terrestrial ecosystems like forests (Carbon Market Institute, 2021). Nature-based carbon sequestration projects are still in their early stages of development in the Asia-Pacific region, but there is significant potential for growth (Carbon Market Institute, 2021; United Nations Environment Programme, 2022). Most projects have been concentrated in a few countries, and most of these projects have involved forestry and revegetation. However, there is also significant untapped potential for nature-based carbon sequestration projects in many other countries in the region, particularly in island countries. There are investment opportunities to invest in nature-based solutions in the coastal and marine ecosystems of the region. The expansion of initiatives such as mitigation banking and the development of methodologies such as blue carbon could attract the interest of private sector actors (Carbon Market Institute, 2021; Climate Focus, 2011; Gordon et al., 2011).

This assessment provides a comprehensive overview of the status of key regional ecosystems as carbon dioxide sinks and documents the changes in key ecosystems in Asia-Pacific, including mangroves, seagrass, coral reefs, forests, cropland, and mountain glaciers. The outcome of this assessment will answer the following questions i) What is the status of key ecosystems, including mangrove, seagrass and coral reef, in the Asia-Pacific region and what are the key changes or trends? ii) How are current trends impacting the capacity of ecosystems to store or release carbon and deliver other ecosystem services in the region?, and iii) based on these findings what would be the ecosystems recommended as areas for priority investment?

To assess potential shifts within these ecosystems, this evaluation leverages both global and regional datasets, along with estimates, to map and monitor key indicators. The findings presented in this assessment are derived from a desktop analysis of regional and global

assessments regarding changes in ecosystems, as well as the calculation spatial overlay analysis of indicators specific to the Asia-Pacific region. These estimates regarding the state and transformations of various ecosystem types are derived from a time series of remote sensing products developed by the ESCAP, United Nations Environment Programme (UNEP), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Framework Convention on Climate Change (UNFCCC), the World Resources Institute (WRI), Global Mangrove Watch (GMW), and other published scientific and knowledge products.

Chapter 1: State of Key Coastal Ecosystems in the Asia Pacific

Mangroves, seagrass meadows and coral reefs are all coastal ecosystems which are powerful allies against climate change by providing invaluable natural services, including sequestering carbon dioxide, boosting biodiversity, protecting our coasts from rising sea levels and sea surges, and supporting local livelihoods and as drivers of national economies (Duţescu et al., 2019).

The Millennium Ecosystem Assessment (MA) (Duţescu et al., 2019), a major UN-sponsored effort to analyse the impact of human actions on ecosystems and human well-being, identified four major categories of ecosystem services: provisioning (e.g., food, water, and fuel), regulating (e.g., climate regulation, water, and disease), cultural (spiritual, aesthetic, recreation, and education) and supporting services (e.g., primary production, and soil formation). The ecosystem services provided by these ecosystems include carbon storage, biodiversity, freshwater systems, drought protection, and climate regulation and amelioration (Duţescu et al., 2019).

Mangroves, on their own, contribute greatly to our ocean's health. However, with the added presence of seagrass and coral reefs, the three combine forces and flourish as a collective, made stronger by the success of the others. This section focuses on the status and changes in the coastal ecosystems including mangroves, seagrass, and coral reefs. This assessment is based on a range of global and regional spatial data sets, tools, reports, and published literature to understand the trends in regional trends of ecosystem indicators.

The vulnerable impacts of sea level rise, coastal flooding, cyclones, and erosion can lead to serious implications for the environmental and socioeconomic services provided by the coastal ecosystem including disruption of livelihoods, food production, human wellbeing, and other economic losses. This chapter emphasises the identification of ecosystem services at risk in the Asia Pacific region. Changes in key climate indicators will be documented to identify climate hazards and impacts of climate change on coastal ecosystem services and their associated communities. The assessment report for these indicators is based on the current works of ESCAP on climate change, and other global and regional studies on coastal ecosystems.

Coastal ecosystems serve as the foundation for coastal fisheries (Saintilan et al., 2023). They have a crucial role in supporting 95% of commercially valuable fish worldwide by serving as essential nursery habitats for juveniles (Jänes et al., 2020). Moreover, these ecosystems are well-placed nature-based solutions to contribute to CO2 removal in efforts to maintain warming below 2 °C (Saintilan et al., 2023).

Coastal ecosystems, such as mangroves, seagrass, and coral reefs, are important natural barriers protecting coastal communities. These ecosystems can naturally adapt to sea level rise by building vertically and expanding laterally. However, fragmentation of wetland habitats due to the direct influence of anthropogenic activities, coastal ecosystems progressively lose their ability to adapt to climate-induced changes which damage important ecosystem services such as coastal protection and ecosystem services. Coastal ecosystems are already being affected by the combined effects of human activities (habitat loss, overfishing, pollution, agricultural run-

off), and climate-related changes (ocean warming, sea level rise, and ocean acidification) (IPCC, 2022a). Combined degradation of the interlinked coastal ecosystems (mangroves, coral reefs, seagrass) is causing aggravated loss of biodiversity and associated ecosystem services in the Asia and Pacific region (IPBES, 2018).

Coastal risks are dynamically increasing due to observed changes in coastal infrastructure, community livelihoods, agriculture, and habitability. It is difficult to attribute these changes to sea level rise (SLR) and/or climate change because of other factors that can also cause changes, such as demographic, resource, and land use changes, and anthropogenic subsidence (IPCC, 2022a).

Mangrove Forest in the Asia Pacific

Mangroves are the dominant vegetation in the intertidal zone of sheltered (muddy) coastlines found in tropical, sub-tropical, and warm temperate oceans. The term 'mangrove' is used to describe both a specific type of vegetation and a distinctive habitat which is also referred to as tidal forest, swamp, wetland, or mangal (Duke et al., 2007; Spalding, 2010). The mangrove habitat is characterized by a continuum of features, including mudflats (zone below mean sea level), mangrove forests (zone between mean sea level and the level of higher neap tides), and salt flats (zone above the level of higher neap tides). The distribution of these features may vary across space and time due to variations in climate, topography, and hydrology (Woodroffe, 1992).

Dynamics of Mangrove Cover Changes

Mangroves spanned over ~147,359 km2 worldwide in 2020, with 51% of those forests (74,808 km2) located in the Asia-Pacific (Figure 1). Globally, mangrove forest has decreased by 5,245 km2 (3.4%) between 1996 and 2020, out of which 63% mangrove loss is recorded in the Asia-Pacific with the largest net loss of 4.3 % (3,338 km2) mangrove forest cover (Figure 4, Figure 2, Figure 3, Table 1). However, over the last decade, between 2010 to 2020, the net loss in mangrove cover has declined to 420 km2 (0.05%) from 2918 km2 (3.73%) during 1996 – 2010 (Bunting et al., 2022; Leal and Spalding, 2022; UNEP, 2023a)**.**

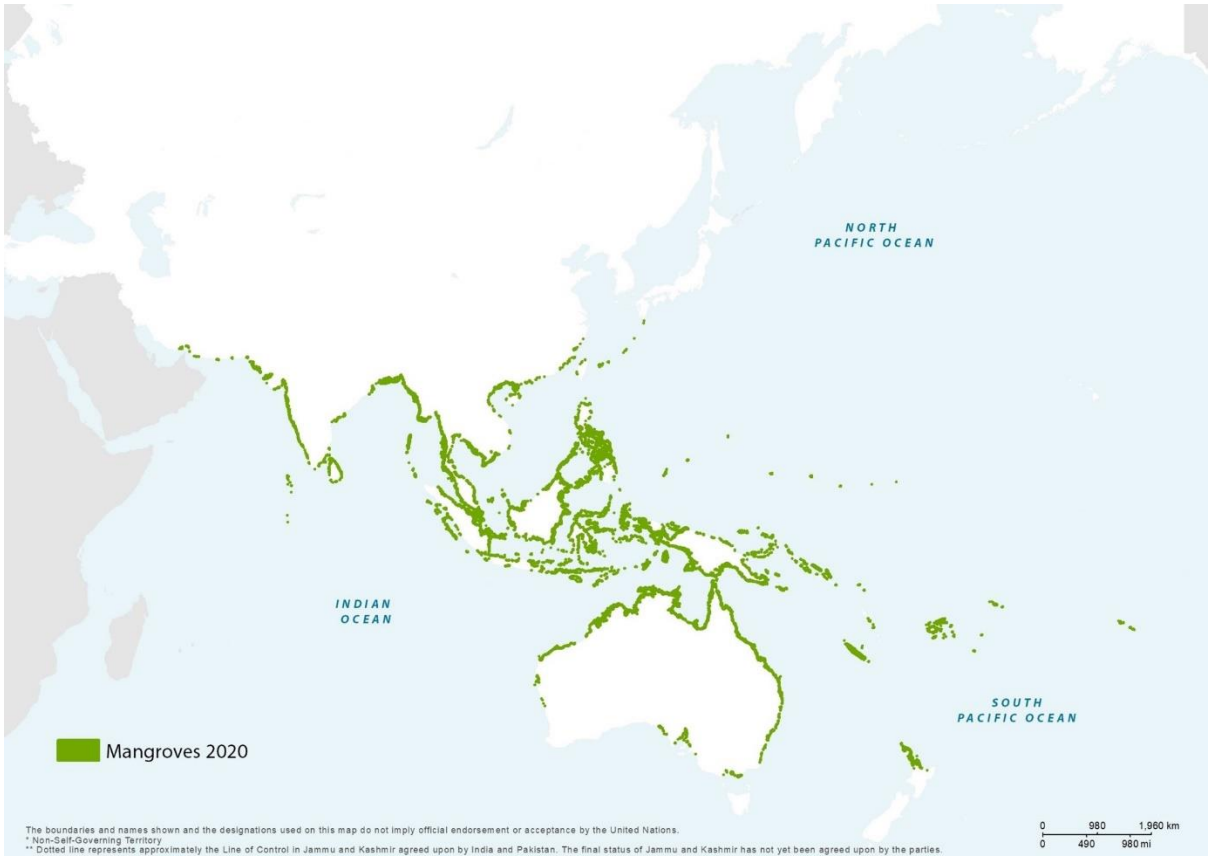

Figure 1 Spatial distribution of mangrove forest cover in the Asia-Pacific.

The mapped mangrove in 2020 (Bunting et al., 2022)
Source: Author's compilation from (Bunting et al., 2022)

Mangrove cover is declining fastest in Asia-Pacific, of all global regions; losses have slowed in the last ten years.

Almost half of the world's mangroves are found in Asia, and this region accounted for most of the mangrove area loss in both the 2000-2010 and 2010-2020 periods **(**Figure 4**,** Table 1**)**. In the first decade, Asia accounted for 68% of global mangrove-area loss, and in the second decade, this figure decreased to 54%. The most significant cause of mangrove loss is aquaculture development, followed by natural retraction. Other causes include conversion to oil palm and rice cultivation, direct settlement, wood extraction, natural disasters and indirect settlements (FAO, 2023).

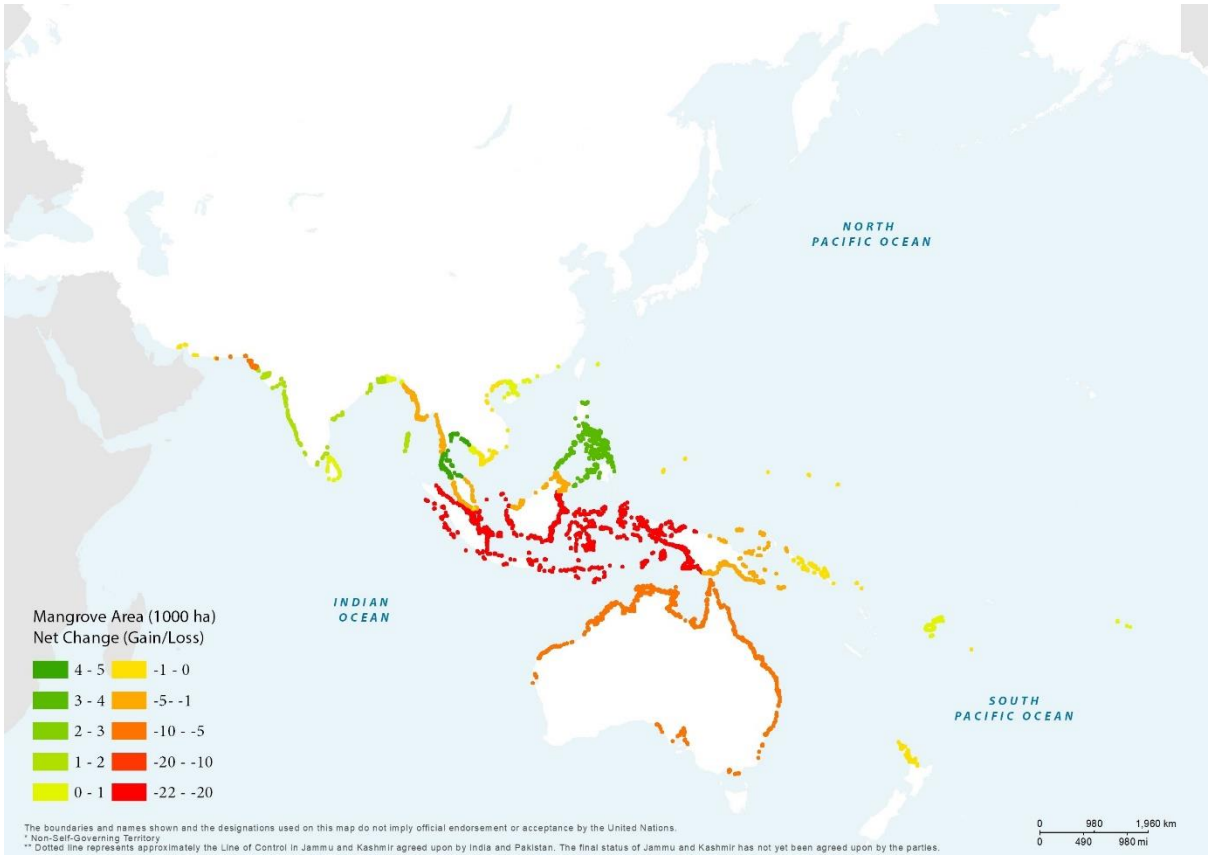

Figure 2 Net Change in mangrove cover area in the Asia Pacific aggregated at the country level.
The net change is estimated from the mapped mangrove area in 2010 and 2020 (Bunting et al., 2022; Leal and Spalding, 2022; UNEP, 2023a). *The mapped area may not be comparable with other country-level or delta-specific studies due to multiple factors and reporting mechanisms.*
Refer to (Table 3) for more details on the extent and changes in mangroves in the ESCAP countries.
Source: Author's compilation from the sources mentioned above

Table 1 Change in mangrove forest cover extent over the last four decades, from 1980 – 2020.
The figures for 1980 and 1990 are from the FAO's assessments which come from different sources and may not be consistent with the figures from 1996 to 2020, which come from the consistent estimates of global mangrove forest extents (Bunting et al., 2022).

Region	Year	Extent (km2)	Annual change (km2)	Change from 1996 (km2)	Change from 1996 (%)
Asia-Pacific	1980	98950.00			
	1990	87820.00			
	1996	78,146.35			
	2007	76,413.79	-157.51	-1,732.56	-2.22
	2008	75,596.75	-817.05	-2,549.61	-3.26
	2009	75,471.84	-124.90	-2,674.51	-3.42
	2010	75,228.34	-243.51	-2,918.02	-3.73
	2015	74,811.38	-83.39	-3,334.97	-4.27
	2016	74,637.03	-174.36	-3,509.33	-4.49
	2017	74,669.22	32.20	-3,477.13	-4.45
	2018	74,784.23	115.00	-3,362.13	-4.30
	2019	74,813.69	29.47	-3,332.66	-4.26
	2020	74,808.56	-5.13	-3,337.79	-4.27

Source: Author's compilation from the sources mentioned above
Note: Due to the recent advancement in technologies and the increase in the capacity of different countries to map and quantify national forest resources, these maps and area statistics may not be consistent with other global, regional, and national level assessments.

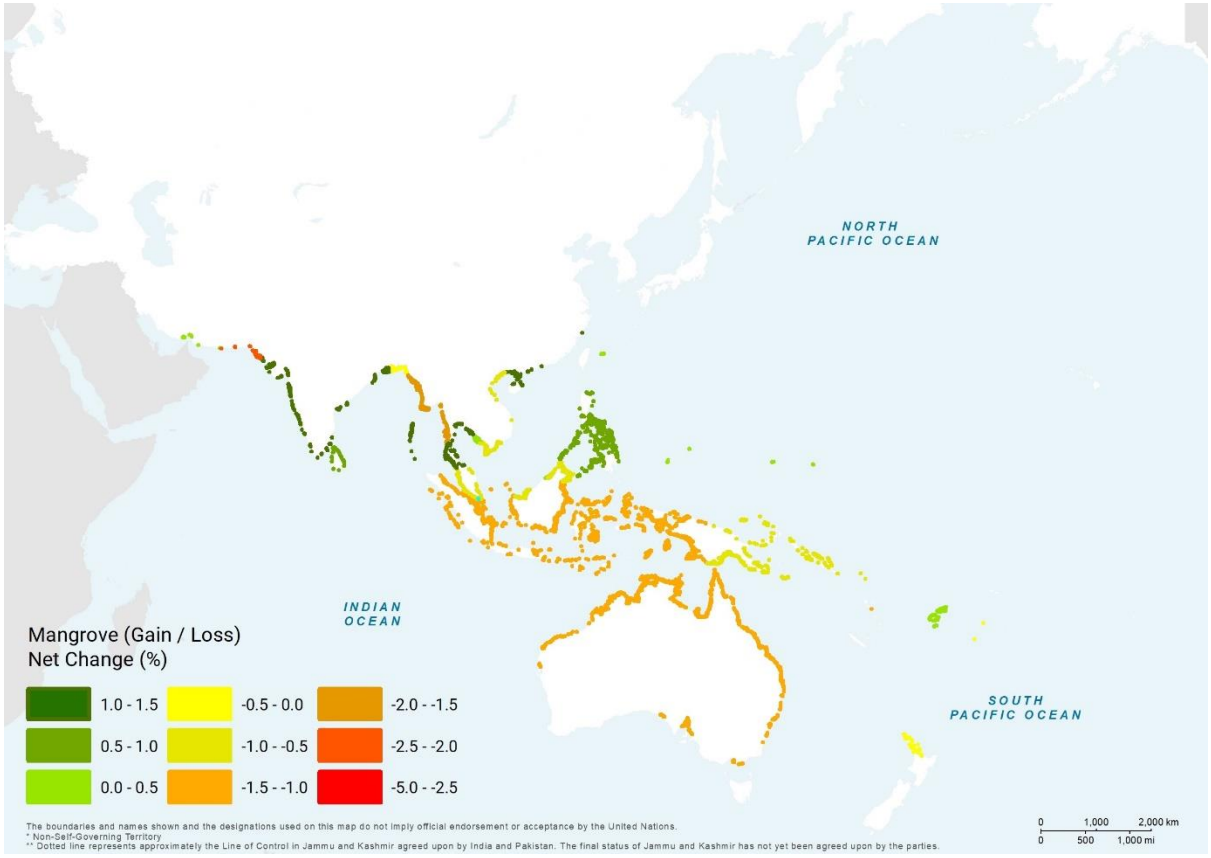

Figure 3 Net Change in mangrove cover area in the Asia Pacific aggregated at the country level.

The net change is estimated from the 3-yearly average of the annual mapped area of mangroves from 2008 to 2010 and 2018 to 2020 (Bunting et al., 2022; Leal and Spalding, 2022; UNEP, 2023a). *The 3-yearly averages were taken to normalize noise or abrupt changes that might come from area estimation of consecutive years. However, the mapped area may not be comparable with other country-level or delta-specific studies due to multiple factors and reporting mechanisms.*
Refer to (Table 3) for more details on the extent and changes in mangroves in the ESCAP countries.
Source: Author's compilation from the sources mentioned above

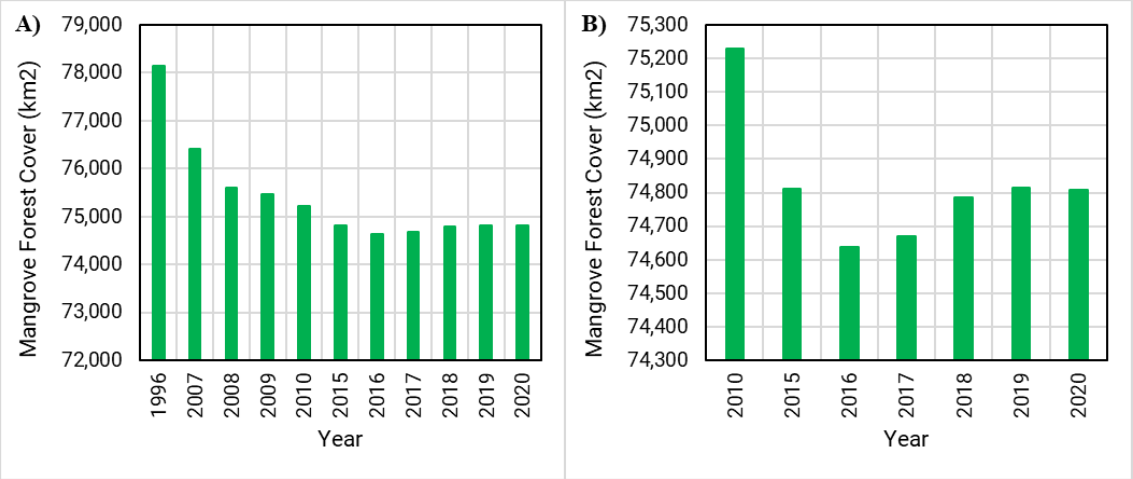

Figure 4 Changes in mangrove forest cover from 1996 to 2020 in the Asia Pacific Region, a)1996 – 2020, b)2010 – 2020 (Leal and Spalding, 2022; UNEP, 2023a)
Source: Author's compilation from the sources mentioned above (Leal and Spalding, 2022; UNEP, 2023a)

In 2020, Asia had the largest area of mangroves in the world, with 6.5 million ha, or 44% of the global total. East Asia is the only region where mangrove area has increased in the past 20 years, at a rate of 2.32% per year. Almost all of Asia's mangroves (99.5%) are in South and Southeast Asia, where the annual rate of net loss in mangrove cover has declined from 0.23% in 2000-2010 to 0.11% in 2010-2020.

The Asia-Pacific region was responsible for 70 % of the global net loss of carbon stored in mangrove forests in the last 25 years – these losses are globally significant

Mangrove forests, found in tropical regions, stand out as some of the most carbon-dense ecosystems, boasting an average of 1,023 Mg of carbon per hectare. This remarkable carbon storage capacity, which is primarily attributed to their waterlogged soil conditions, is estimated to be up to four times greater than that of certain other forested environments like temperate and boreal forests (Donato et al., 2011). Given the substantial carbon reservoir within mangroves, it becomes imperative to protect these existing areas to mitigate potential future CO2 emissions (Leal and Spalding, 2022).

Between 1996 and 2020, the amount of carbon stock stored in mangrove forests decreased by 139 Mt (UNEP, 2023). This loss represents only an estimated 0.6 per cent of the total emissions from land use change, and less than 0.1 per cent of the total global CO2 emissions (Worthington and Spalding, 2018). The Asia-Pacific region had a net loss of 98 Mt of carbon (358 Mt CO2

)[3] stored in mangrove forests during 1996-2020. An estimated 184 Mt of carbon (674 Mt CO2) was lost in the Asia Pacific with Indonesia experiencing the greatest losses, followed by Australia, while the gain in mangrove cover in the region can provide 86 Mt of carbon storage (314 Mt CO2) with the largest net gain in Bangladesh. The net losses in the Asia Pacific region comprise 70 % of the global net loss of 139 Mt carbon (508 Mt CO2) stored in mangrove forests with a total gain of 168 Mt carbon (614 Mt CO2) and loss of 308 Mt (1127 Mt CO2) during 1996-2020 (UNEP, 2023a).

Mangroves store a large amount of carbon of which around 87% of the carbon is stored in the soil. Th decrease in mangroves cover is a major concern, as mangroves are important carbon sinks that help to mitigate climate change. At the global scale, mangrove forests store 6.23 gigatonnes (Gt) of carbon, equivalent to 22.86 gigatonnes of CO2. For instance, the loss of just 1% of the current mangroves (~1500 km2), or 2% of mangroves in the Asia Pacific, could lead to an equivalent loss of 230 megatons of CO2 equivalent equating to over 520 million barrels of oil, or the annual emissions of 49 million cars in the USA. Therefore, it is critical to protect, conserve and prevent the degradation of mangrove ecosystems (Leal and Spalding, 2022).

Mangroves Ecosystem Services

A major regulating service provided by mangrove ecosystems is carbon sequestration (IPCC, 2022b). Annually, mangrove ecosystems deliver approximately US$193,843 in ecosystem services per hectare (Costanza et al., 2014). With an extent of 7.48 million hectares, the annual value of ecosystem services provided by the mangroves in the Asia Pacific amounts to US$1.5 trillion. On a global scale, mangrove forests have experienced a reduction of 5,245 km2 (3.4%) between 1996 and 2020. Notably, the Asia-Pacific region accounts for 63% of global mangrove loss, with a net decline of 4.3% (3,338 km2) in mangrove forest cover (Bunting et al., 2022; Leal and Spalding, 2022; UNEP, 2023a). This amounts to an annual loss of US$64.7 billion from the ecosystem services provided by the mangroves (Costanza et al., 2014).

In Southeast Asia, considering a baseline scenario of mangrove loss from 2000 to 2050, the projected annual ecosystem services losses in 2050 amount to approximately $2.2 billion. This estimate comes with a prediction range of $1.6 billion to $2.8 billion. The average and middle values for mangrove ecosystem services amount to 4185 and 239 US$/ha/year, respectively. The variability in these values across different study sites (Brunei, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Thailand, and Viet Nam) can be attributed to various factors, including the site's biophysical characteristics and the socio-economic attributes of the beneficiaries of these ecosystem services (IPBES, 2018; M. Brander et al., 2012).

It's worth noting that around 75% of the world's commercial shrimp production takes place in Asia, making it a significant economic activity with expected future growth (Hamilton and Casey, 2016). Mangroves are critical to the livelihoods of millions of fishers around the world. They provide important breeding and nursery grounds for many fish and shellfish species, and they also offer protection from storms and coastal erosion. Globally, there are an estimated 4.1

[3] C - CO2 Conversion Factor is 3.67 (IPCC, 2007)

million mangrove-associated small-scale fishers, with the highest number found in Indonesia, India, Bangladesh, Myanmar, and Brazil. Mangrove fishing intensity is greatest in Asia (zu Ermgassen et al., 2020). In Indonesia alone, mangroves are essential to an estimated 893,000 small-scale fishers. Other ESCAP countries in the top 10 with the greatest number of mangrove fishers globally include India (570, 000), Bangladesh 286,000, Myanmar (286,000), Viet Nam (240,000), Thailand (27,000) and Philippines 118,000 (Leal and Spalding, 2022).

Mangroves have been valuable resources for people living in coastal areas for centuries. They provide a variety of important services, such as protection from natural disasters, enhancement of fisheries, and pollution control (FAO, 2023). Changes in the extent of mangrove forests can have a significant impact on the socio-economic well-being of millions of people. By taking into account estimates of the proportion of mangrove-dependent small-scale fishers and the net change in mangrove coverage, it becomes feasible to identify countries and territories where mangrove fishers may have experienced significant effects. (UNEP, 2023a)

Mangrove loss is a serious problem in the Asia Pacific region, especially in Southeast Asia. It is important to continue efforts to address the land use drivers of mangrove loss. This includes developing policies to direct agricultural development in a way that avoids deforestation of remaining mangrove forests and the devastation of the coastal habitat. The role of climate change as a contributing factor to the natural decline of mangroves and/or their ecosystem services should be recognised, as this exacerbates the vulnerability of coastal communities to natural disasters, inundation of mangroves, and coastline erosion (FAO, 2023).

Mangroves at Risk

Mangrove in the Asia-Pacific region is the most diverse in the world providing a variety of benefits to communities, including food, shelter, and protection from storms. The rate of mangrove loss in the Asia Pacific region is alarming, especially in South-East Asia. Despite growing awareness and a recent slowdown in global mangrove deforestation, Southeast Asia is still experiencing mangrove loss at rates ranging from 3.58% to 8.08% per year. Degradation and loss of mangrove habitat due to natural (sea level rise, storms, global warming) and anthropogenic (conversion to oil palm, indirect settlements, aquaculture) stressors are leading to the loss of important ecosystem services, such as coastal protection, carbon storage and support provided to global and local fisheries. The loss of mangroves will lead to the discontinuation of critical ecosystem services, which will make coastal communities, particularly low-lying coastal communities more vulnerable to natural disasters and climate change. Mangrove losses are likely caused by a combination of direct human impacts and harder-to-manage changes. This could have a devastating impact on people and nature in the Asia-Pacific region (IPBES, 2018; Leal and Spalding, 2022).

Up to 75 per cent of the mangroves in the Asia-Pacific region have been degraded or converted in recent decades. There has been a notable increase in the conversion of mangroves to various land uses, including aquaculture, rice cultivation, and oil palm plantations, among others. This conversion is jeopardizing their crucial role in mitigating the impact of natural disasters such as cyclones and tsunamis.

Possible Causes of Risk to the Mangrove Ecosystem

The future of mangroves in the Asia Pacific region will ultimately be shaped by a combination of both climatic and non-climatic direct drivers (Table 2). Climate change is impacting mangroves at regional scales through a variety of interrelated and spatially variable factors, including sea level rise, increased storminess, altered precipitation regime, and increasing temperature (Table 2). The complex interplay of these factors directly affects the productivity of mangrove ecosystems, increases erosion, and salinity, alters sediment supply, and threatens the drowning of mangroves (Giri et al., 2011; IPCC, 2014; Ward et al., 2016). More discussion on drivers of mangroves losses is given in the Annexes (Annex I. Drivers of Mangroves Losses in the Asia Pacific)

The impact of rising sea levels will be most pronounced in mangrove areas where the sediment elevation is decreasing and there is limited space for landward migration (Gilman et al., 2008). Rising sea levels due to global warming pose the most significant threat to mangroves, impacting their contributions to the well-being of people, especially in countries like Bangladesh, the Philippines, New Zealand, Viet Nam, and China (IPBES, 2018). The impact of rising sea levels is expected to affect mangroves in all regions, but the specific consequences at the local level are likely to exhibit greater variation (Ward et al., 2016).

Mangrove sediment surface elevations, in most cases, are not keeping pace with rising sea levels, although more comprehensive, long-term studies from a wider range of regions are required to fully understand this phenomenon. Pacific Islands' mangroves are highly vulnerable to significant reductions. While there is less certainty about other potential climate change outcomes and mangrove responses, there is a pressing need for further research to develop assessment methods and standard indicators that can gauge these responses to climate change effects. Regional monitoring networks should also be established to systematically observe these responses and inform informed adaptation strategies (Gilman et al., 2008).

Among non-climatic drivers such as human-induced alterations in land use, urbanization, and the expansion of agriculture and aquaculture will likely be the primary drivers of change in mangrove habitats, particularly in the near and short-term future. However, the extent of these changes will vary across different subregions. The increasing demand for land makes small island mangrove habitats especially vulnerable to future alterations, putting them at risk of local extinction (IPBES, 2018).

Table 2 Regional distribution of mangrove cover in the Asia Pacific (Giri et al., 2011), Species richness and likely impacts of climate change factors by 2100 (IPCC, 2014; Ward et al., 2016)

Region	Mangroves Area (ha)	Percentage of Global Mangrove	No. Species	Sea Level Rise (mm/yr)	Temperature Increase	Precipitation Change	Tropical Cyclone Increase
Asia	5776173	41.9	55	2.0–5.4	Very likely	Very likely (+)	Likely
Australia New Zealand	1009713	7.3	36 (1 NZ)	2.0–3.8	Very likely	Very likely (+)	Likely
Pacific	623755	4.5	35	1.4–2.0	Very likely	Very likely (+)	Likely

The primary non-climatic of mangrove loss in the Asia-Pacific region, particularly in Southeast Asia, is the expansion of agriculture into existing mangrove habitats, followed by a rapid increase in brackish water aquaculture (Figure 5). Rice agriculture has been a major driver of mangrove loss in Myanmar (Estoque et al., 2018; Richards and Friess, 2016; Webb et al., 2014; Zöckler and Aung, 2019). It has been projected that unless a suitable balance is achieved locally, mangroves in the Ayeyarwady (Irrawaddy) Delta of Myanmar could vanish by 2030 due to the ongoing rate of agricultural expansion (Webb et al., 2014). The expansion of oil palm plantations and conversion of mangroves to ponds is anticipated to pose a growing threat to mangrove forests in Southeast Asia, especially in Indonesia and Papua, by leading to mangrove deforestation, habitat loss, and biodiversity decline (Prakoso et al., 2023; Richards and Friess, 2016). Additionally, the extensive mangrove die-back in the Gulf of Carpentaria, Australia, in late 2016, which affected an area of around 7,000 hectares, is likely due to an extended drought period (Duke et al., 2017).

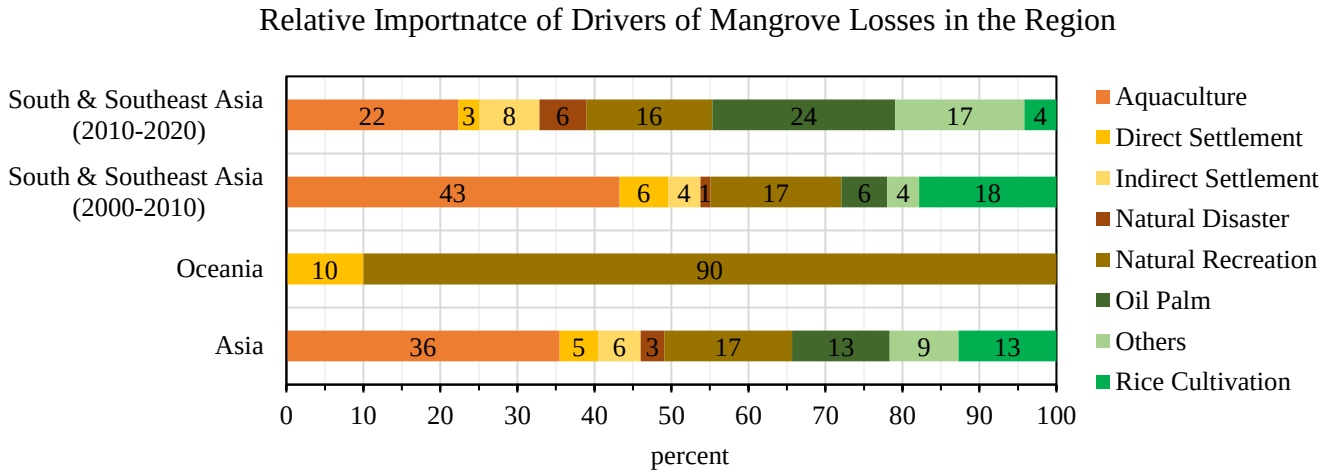

Figure 5 Composition of the relative importance of regional drivers of mangrove losses
Source: Author's compilation from (FAO, 2023)

Over the past two decades, the main drivers of mangrove loss in the sub-regions were aquaculture, accounting for 35% of the loss, natural retraction (17%), conversion for rice cultivation (13%), oil palm (13%), and the remainder (22%) comes from the other sources including natural disasters, direct and indirect settlements (Figure 5). Notably, over the last decade, the role of aquaculture, conversion to rice and direct settlement has declined while the conversion to oil palm plantations emerged as the dominant driver of mangrove loss. A significant increase in loss due to natural disasters and indirect settlement is also reported in the region (FAO, 2023).

However, countries like India, Bangladesh, and Pakistan have been relatively successful in maintaining a stable mangrove extent (Giri et al., 2014). These countries have established an extensive network of protected areas that have played a crucial role in preserving mangroves, despite substantial population pressure in the vicinity (IPBES, 2018).

Key Message:

Asia Pacific is home to half the world's mangroves but facing growing threats to their exceptional diversity.

In 2020, the global extent of mangroves covered approximately 147,359 km2, and the Asia Pacific region played a significant role, hosting nearly half of the world's mangroves, with an area of 74,808 km2. The Asia-Pacific mangroves are renowned for their exceptional diversity. However, this vital ecosystem faces a severe threat, particularly in Southeast Asia, where mangrove loss is a critical concern.

Mangroves deforestation is slowing is the region, yet bearing 63% of global loss

Between 1996 and 2020, the Asia Pacific region witnessed a net loss of 3,338 km2, which accounts for a substantial 63% of the global mangrove loss. Encouragingly, the net mangrove loss in the Asia Pacific has decreased from 2,918 km2 during 1996-2010 to 420 km2 in the last decade from 2010 to 2020. This decline is a positive development. Still, it's important to note that the region experienced a net loss of 98 Mt of carbon stored in mangrove forests between 1996 and 2020, representing 70% of the global net loss. Indonesia and Australia experienced the highest losses, while Bangladesh emerged as a leader in carbon gain.

Conversion to oil palm, aquaculture and rice cultivation are the changing forces behind mangrove loss in South and Southeast Asia

The primary drivers of mangrove loss in South and Southeast Asia have evolved, with aquaculture, natural retraction, rice cultivation, and oil palm all playing significant roles. In recent years, the conversion to oil palm plantations has emerged as the dominant driver of mangrove loss. The degradation and loss of mangrove habitats due to natural and anthropogenic stressors pose significant threats to both people and nature in the Asia-Pacific region, particularly in countries like Bangladesh, the Philippines, New Zealand, Viet Nam, and China. Additionally, recognizing the contribution of climate change to mangrove decline and its impact on coastal communities and ecosystems is of utmost importance, as it exacerbates vulnerabilities to natural disasters, mangrove inundation, and coastal erosion.

Table 3 Extent of mangroves in the ESCAP countries.
Data Source: The data is extracted from (Bunting et al., 2022), *Global Mangrove Watch Version 3.0 (GMW v3.0). The net change (**Gain/Loss during 2008-10 to 2017-20)** is estimated from the 3-yearly average of the annual mapped area of mangroves from 2008 to 2010 and 2018 to 2020* (Bunting et al., 2022; Leal and Spalding, 2022; UNEP, 2023a). *The 3-yearly averages were taken to normalize noise or abrupt changes that might come from area estimation of consecutive years. However, the mapped area may not be comparable with other country-level or delta-specific studies due to multiple factors and reporting mechanisms.*

Country	**1996**	**2010**	**2020**	**Gain/Loss 1996-2020**		**Gain/Loss 2010-2020**		**Gain/Loss 2008/10-2018/20**	
	Area (ha)			Area (ha)	%	Area (ha)	%	**Area (ha)**	%
American Samoa	33	32	32	-0.55	-1.68	-0.14	-0.43	0.03	0.09
Australia	1,065,472	1,026,256	1,017,081	-48,391.26	-4.54	-9,175.68	-0.89	-10,482.10	-1.02
Bangladesh	444,717	447,661	448,386	3,668.63	0.82	725.04	0.16	-41.87	-0.01
Brunei	11,462	11,482	11,497	34.96	0.30	14.66	0.13	13.23	0.12
China	24,499	21,134	21,581	-2,918.52	-11.91	446.48	2.11	262.71	1.22
Cook Islands	3	3	3	0.00	0.00	0.00	0.00	0.00	0.00
Fiji	48,572	48,772	48,814	241.95	0.50	42.73	0.09	86.15	0.18
Micronesia	9,084	9,017	8,794	-289.15	-3.18	-222.25	-2.46	24.09	0.27
Guam	52	52	52	0.38	0.73	0.38	0.73	-0.08	-0.15
Indonesia	3,127,302	2,974,865	2,953,398	-173,903.84	-5.56	-21,466.44	-0.72	-37,565.22	-1.26
India	411,119	402,496	403,785	-7,333.94	-1.78	1,288.35	0.32	4,094.91	1.02
Iran	14,269	11,469	11,177	-3,092.42	-21.67	-291.93	-2.55	15.66	0.14
Japan	1,036	1,019	1,031	-4.87	-0.47	11.78	1.16	3.68	0.36
Cambodia	64,656	62,053	62,692	-1,963.90	-3.04	638.64	1.03	57.24	0.09
Kiribati	146	146	146	0.00	0.00	0.00	0.00	0.00	0.00
Sri Lanka	25,861	19,734	19,874	-5,986.90	-23.15	140.81	0.71	112.40	0.55
Maldives	97	97	97	0.00	0.00	0.00	0.00	0.00	0.00
Marshall Islands	33	33	33	0.00	0.00	0.00	0.00	0.00	0.00
Myanmar	582,120	548,406	543,539	-38,581.14	-6.63	-4,867.17	-0.89	-10,761.97	-1.96
Malaysia	531,482	528,082	524,575	-6,906.92	-1.30	-3,507.43	-0.66	-3,045.36	-0.58
New Zealand	29,027	29,998	29,608	581.07	2.00	-389.33	-1.30	-79.42	-0.27
Pakistan	100,002	89,579	82,789	-17,213.56	-17.21	-6,790.74	-7.58	-2,190.71	-2.42
Philippines	292,732	281,275	284,798	-7,934.19	-2.71	3,522.79	1.25	2,453.88	0.87
Palau	5,662	5,700	5,688	25.91	0.46	-12.31	-0.22	9.12	0.16
Papua New Guinea	457,348	457,051	452,474	-4,873.92	-1.07	-4,577.48	-1.00	-4,171.32	-0.91
French Polynesia	122	120	125	2.98	2.44	5.45	4.55	3.50	2.91
Singapore	840	775	730	-110.66	-13.17	-44.81	-5.79	-37.63	-4.90
Solomon Islands	52,731	52,898	52,651	-79.95	-0.15	-247.68	-0.47	-371.48	-0.70
Thailand	259,819	247,975	252,799	-7,020.00	-2.70	4,823.41	1.95	2,813.18	1.13
Tonga	1,055	1,068	1,043	-12.09	-1.15	-25.39	-2.38	-5.01	-0.47
Tuvalu	9	9	9	0.00	0.00	0.00	0.00	0.00	0.00
Viet Nam	196,419	188,134	187,147	-9,272.27	-4.72	-986.91	-0.52	-1,437.46	-0.76
Vanuatu	1,623	1,637	1,584	-39.36	-2.43	-52.85	-3.23	-17.48	-1.07
Samoa	234	239	232	-1.77	-0.76	-6.50	-2.72	-8.24	-3.44
Total Mangroves in ESCAP	7,759,639	7,469,268	7,428,264	-331,375	-4.27	-41,004.52	-0.55	-60,265.56	-10.78
Net Change 1996-2020				**-331375**	**-4.27**				
Net Losses 1996-2020				-335931	-4.33				

Net Gains 1996-2020				4556	0.06				
Net Change 2010-2020						**-41005**	**-0.55**		
Net Losses 2010-2020						-52665	-0.71		
Net Gains 2010-2020						11661	0.16		
Net Change 2008-10 - 2018-20								**-60266**	**-0.80**
Net Losses 2008-10 - 2018-20								-70215	-0.94
Net Gains 2008-10 - 2018-20								9950	0.13

Coral Reef in the Asia Pacific

Despite covering less than 0.2% of the global ocean floor, coral reefs are one of the most diverse ecosystems of the work and provide a habitat for about 25% of known marine species. Occurring in more than 100 countries and territories, these reefs are highly recognised for their significant ecological, economic, and social services, estimated to be US$2.7 trillion per year (Souter et al., 2020).

Dynamics of Coral Reef Changes

The Global Coral Reef Monitoring Network (GCRMN) is a network of scientists and organizations established to monitor the status and trends in coral reef ecosystems. It is a part of the International Coral Reef Initiative (ICRI) and operates in 10 regional nodes to collect and disseminate information on coral reef health. Out of these regions, four fall in the Asia Pacific including South Asia, East Asia, Pacific, and Australia (Figure 6, Table 4). In 2019, the Asia-Pacific region supported more than 77% (20 million ha) of the global area of coral reefs (26 million ha) (Souter et al., 2020). Coral reefs provide ecosystem services worth US$ 352,249 per hectare per year (Costanza et al., 2014). With an approximate extent of 20 million ha (Souter et al., 2020), the annual value of ecosystem services provided by the coral reef ecosystems in the Asia Pacific amounts to US$7.1 trillion. Similarly, the global value of annual ecosystem services provided by the 26 million ha of coral reefs could be US$ 9.15 trillion.

Coral reefs have declined by almost one-quarter in the last 15 years.

During the last 15 years, the region has experienced a decline of 22% in average coral cover. The loss of coral cover was accelerated from 3.4% (during the late 2000s to early 2010s) to 18.7% (during the early 2010s to late 2010s). An accumulative loss of 14 % (11,700 km2) in the global hard coral cover area was observed between 2009 and 2018. The hard coral cover is a measure of the percentage of reef surface covered by live hard coral instead of sponges, algae, or other organisms. It is a globally accepted and universally used indicator of coral reef health. The significant loss of hard coral cover is attributed to recurring large-scale coral bleaching events. Coinciding with the loss of hard coral reefs, the presence of algae has increased by 20% since 2011. The algal cover is an indicator of stress on coral reefs (Souter et al., 2020). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (IPBES, 2019) and the Special Report on the Ocean and Cryosphere in a Changing Climate by the Intergovernmental Panel on Climate Change (IPCC) (Oppenheimer et al., 2022) reports provides an alarming insight on the state of coral reefs. More than 50% of the world's coral reefs have already disappeared, and the projected loss could reach 70-90% at a warming of 1.5°C (Souter et al., 2020).

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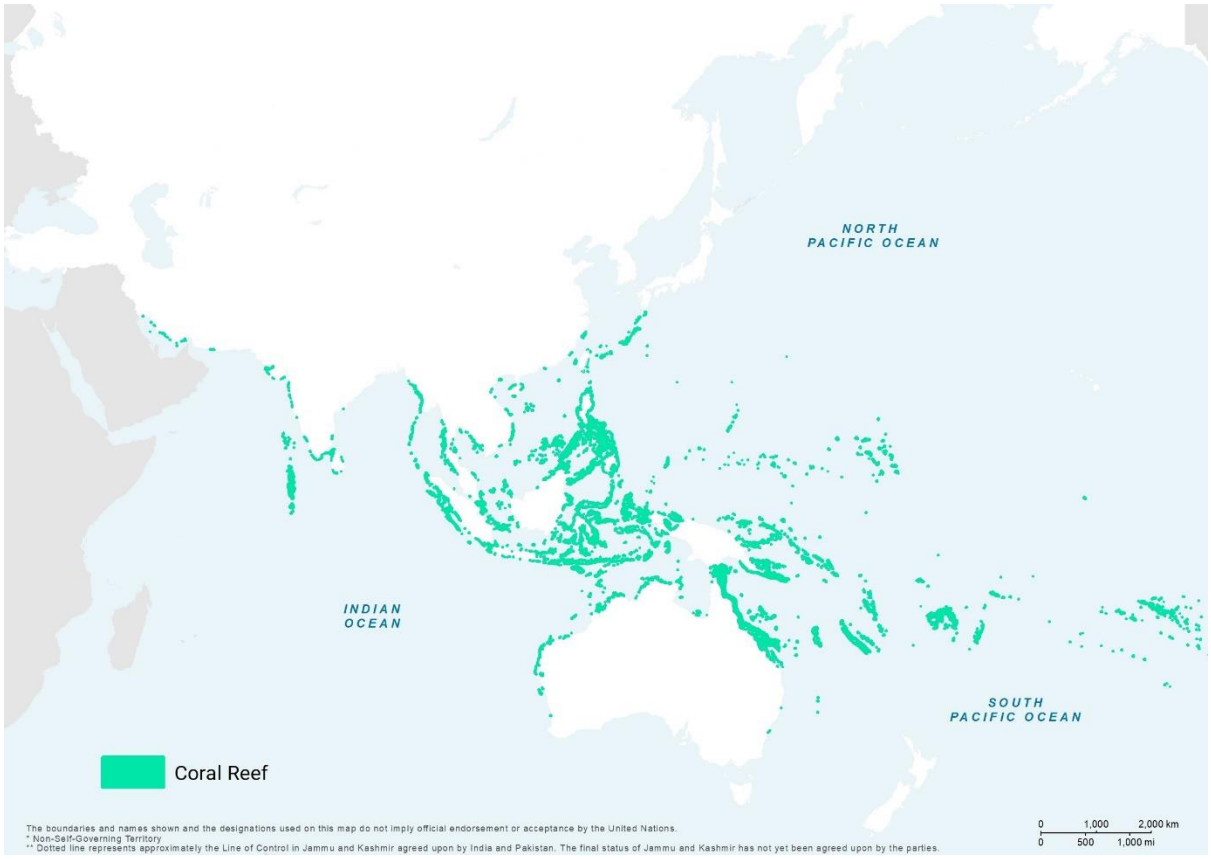

Figure 6 Distribution of coral reefs in the Asia Pacific region
The regions are defined by the Global Coral Reef Monitoring Network (GCRMN) of the International Coral Reef Initiative (ICRI) (Souter et al., 2020) *and the data for the coral reefs was obtained from the Ocean Data Viewer* (UNEP-WCMC, n.d.) *which is based on several data sources including* (IMaRS-USF, 2005; IMaRS-USF and IRD, 2005; Spalding et al., 2001; UNEP-WCMC et al., 2021).
Source: Author's compilation from the sources mentioned above

Table 4 Summary statistics describing the area of coral reefs in each sub-region of the Global Coral Reef Monitoring Network (GCRMN) in the Asia Pacific. Refer to for details on GRMN regions.

Sub-regions	Coral Area km2	Proportion of Global (%)	Mean Absolute Change (%)		
			2005-09 - 2010-14	2010-14 - 2015-19	2005-09 - 2015-19
South Asian	10949	4.22	4.3	-12.9	-8.7
East Asia	78272	30.15	-2.7	-0.2	-2.8
Australia	41,802	16.1	-4.6	-1.7	-6.6
Pacific	69,424	26.73	-0.4	-3.9	-4.3
Asia Pacific	**200447**	**77**	**-3.4**	**-18.7**	**-22.4**
Global Total	259647				

** Iran is a part of the ESCAP countries. However, it is categorised in the Regional Organization for the Protection of the Marine Environment (ROPME) sub-region of the GCRMN. Therefore, Iran is not included in the statistics for the ESCAP region. The whole ROPME sub-regions occupy a tiny proportion (less than 1 %, 2009 km2) of the global reefs.*
Refer to (Table 5) for details on countries/territories in each sub-region.
Source: Author's compilation from (Souter et al., 2020).

The increasing correlation between rising anomalies and sea surface temperature (SST) provides strong evidence that SST is the main cause of large-scale coral bleaching. The cascading impacts of rising SST and pervasive algal dominance within reef ecosystems reduce the favourable habitat essential for marine biodiversity and undermine the ability of reefs to provide essential services. Reefs are highly sensitive ecosystems, greatly threatened by climate change, ocean acidification, land-based pollution, marine pollution, overfishing, and destructive fishing practices. Preserving these ecosystems is vital for the welfare of coastal communities and aligns with the Sustainable Development Goals of the 2030 Agenda (Souter et al., 2020).

Coral reefs are among the most threatened marine ecosystems due to global warming and the acidification of ocean water (IPBES, 2019). Therefore, maintaining the resilience and protection of coral reef ecosystems requires regular monitoring to reduce local anthropogenic pressures such as ocean acidification, land-based pollution, marine pollution, overfishing, and destructive fishing practices along with simultaneous efforts to address global climate change (IPBES, 2019).

Table 5 Global Coral Reef Monitoring Network (GCRMN) sub-regions and countries or territories covering the Asia Pacific region.

Sub-Regions	**No Countries or Territories**	**MEOW**	**Countries and Territories in the Region**
South Asia	7	6	Bangladesh, India, Maldives, Myanmar, Pakistan, Sri Lanka, and the Chagos Archipelago
East Asia	14	24	China, Hong Kong, Taiwan, Japan, South Korea, Brunei Darussalam, Cambodia, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Viet Nam
Australia	17	11	Australia
Pacific	1	24	American Samoa (USA), Commonwealth of the Northern Marianas (USA), Cook Islands, Fiji, Federated States of Micronesia, French Polynesia (France), Main and Northwestern Hawaiian Islands (USA), Kingdom of Tonga, The Republic of Kiribati, Republic of the Marshall Islands, Nauru, New Caledonia (France), Niue, Republic of Palau, Pitcairn (UK), Pacific Remote Island Area (USA), Papua New Guinea, Samoa, Solomon Islands, Tokelau (NZ), Tuvalu, Vanuatu, and Wallis & Futuna (France)

** Iran is a part of the ESCAP countries. However, it is categorised in the Regional Organization for the Protection of the Marine Environment (ROPME) sub-region of the GCRMN. Therefore, Iran is not included in the statistics for the ESCAP region. The whole ROPME sub-regions occupy a tiny proportion (less than 1 %, 2009 km2) of the global reefs.*
Source: Author's compilation from (Souter et al., 2020)

Coral Reef Ecosystem Services

Coral reefs, the "rain forests of the sea", are among the most biologically rich and productive ecosystems on earth (Burke et al., 2011). Coral reefs are essential to the economies and livelihoods of many countries, especially small island nations. Coral reefs provide food, income, and protection from storms for many people around the world, but they are especially

important for small island nations. The livelihoods of millions of people living within 100 km of coral reefs are most likely to depend on reefs and related resources. A healthy, well-managed reef in the Indian or Pacific Oceans can yield between 5 and 15 tons of seafood per square kilometre per year in perpetuity. Other ecosystem services provided by the reefs include shoreline protection, tourism, and disease prevention (Burke et al., 2011). Occurring in more than 100 countries and territories, these reefs are highly recognised for their significant ecological, economic, and social services, estimated to be US$2.7 trillion per year (Souter et al., 2020). Coral reefs provide ecosystem services worth US$ 352,249 per hectare per year (Costanza et al., 2014). With an approximate extent of 20 million ha (Souter et al., 2020), the annual value of ecosystem services provided by the coral reef ecosystems in the Asia Pacific amounts to US$7.1 trillion. Similarly, the global value of annual ecosystem services provided by the 26 million ha of coral reefs could be US$ 9.15 trillion (Costanza et al., 2014; Souter et al., 2020).

Coral Reefs at Risk

Coral reefs are threatened by local and global factors. Over 60% of reefs are threatened by local sources, and 75% are threatened when combined with climate change (Figure 7, Figure 8, Annex III). Figure 9 shows the distribution of categories (varying degrees of risk) of coral reefs at risk from the integrated local and global threats projected from 2030 in the Asia Pacific region (Burke et al., 2011). The compound impact of climate change also increases the severity of degradation (Burke et al., 2012). Coral reefs are of great ecological, economic, and food security importance to the Asia-Pacific region. However, they are facing several threats, including habitat loss and damage, which are causing the death of reef-forming corals. The death of reef-forming corals undermines the resilience of coastal communities and can lead to the collapse of important coastal ecosystems. One-third of reef-building corals in the region are threatened (Huang and Roy, 2015). Loss of habitat quality and heavy damage to entire reefs are major threats to coral reefs in the region (Bellwood et al., 2004). This is having a negative impact on coastal communities and the region's food security. Coral reefs in Southeast Asia are the most diverse on Earth, but they are also the most threatened, more than 95% of the reefs (Burke et al., 2011; IPBES, 2018), half of these are at high risk, primarily from coastal development and fishing-related activities (Bryant et al., 1998). Indonesia has the largest area of threatened coral reefs, with fishing threats being the main stressor on coral reefs (Bruno and Selig, 2007). Over 65% of the coral reefs in the Indian Ocean are under stress due to local threats. Nearly 50% of coral reefs in the Pacific are threatened. The Maldives, the Chagos Archipelago, and the Seychelles are home to some of the most pristine coral reefs in the Indian Ocean. These reefs are under relatively low threat, but overfishing, land-based pollution and coastal development are all potential threats to their long-term health (Burke et al., 2011). Approximately 14% of Australia’s coral reefs are threatened, though it is ranked as the least threatened coral reef region (IPBES, 2018). Coral reefs are already under threat, and some have been lost, especially in South and Southeast Asia. It is estimated that up to 90% of coral will suffer severe degradation by 2050, even under conservative climate change scenarios. Even for the most managed reefs, coral loss rates are estimated at around 1-2% annually (IPBES, 2018).

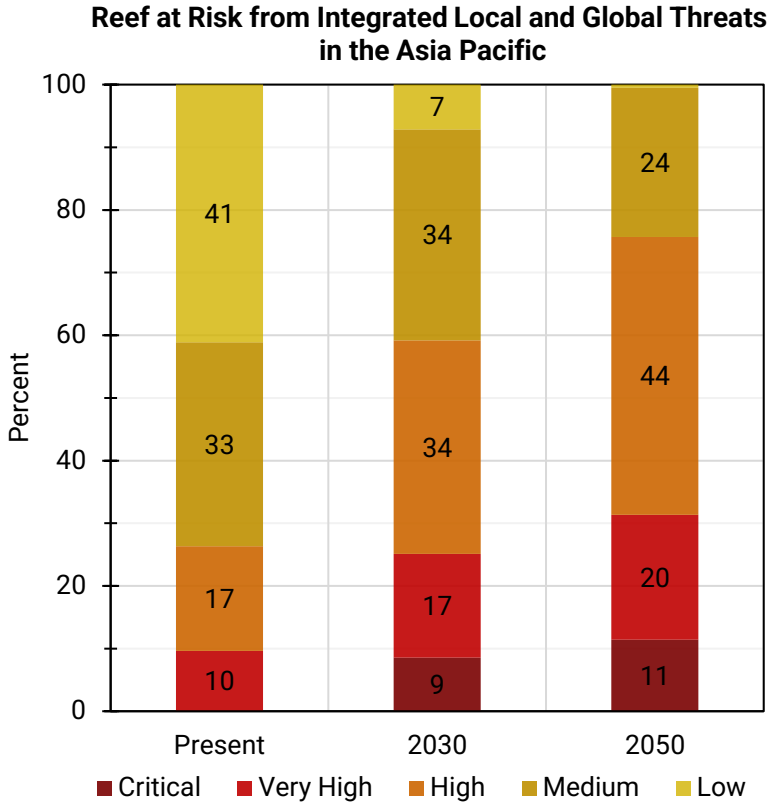

Figure 7 Categorization of the coral reefs at risk from the integrated local and global threats in the Asia Pacific region (Burke et al., 2011).
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, and damage, Overfishing and destructive fishing. Global threats covered Thermal stress (warming sea temperatures, which can induce coral bleaching) and Ocean acidification (driven by increased CO2, which can reduce coral growth rates) (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

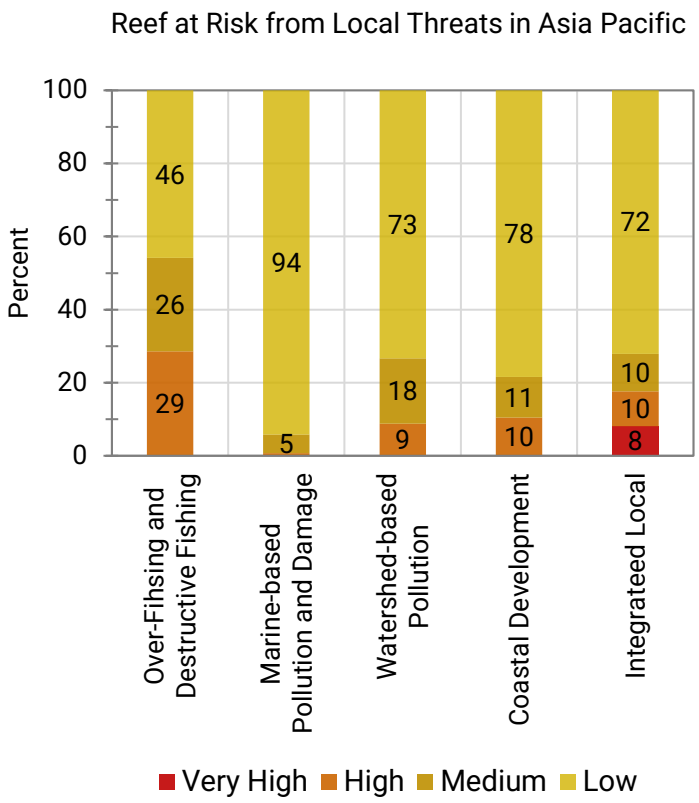

Figure 8 Categorization of the coral reefs at risk from the local threats in the Asia Pacific region (Burke et al., 2011).
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, damage, Overfishing and destructive fishing (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

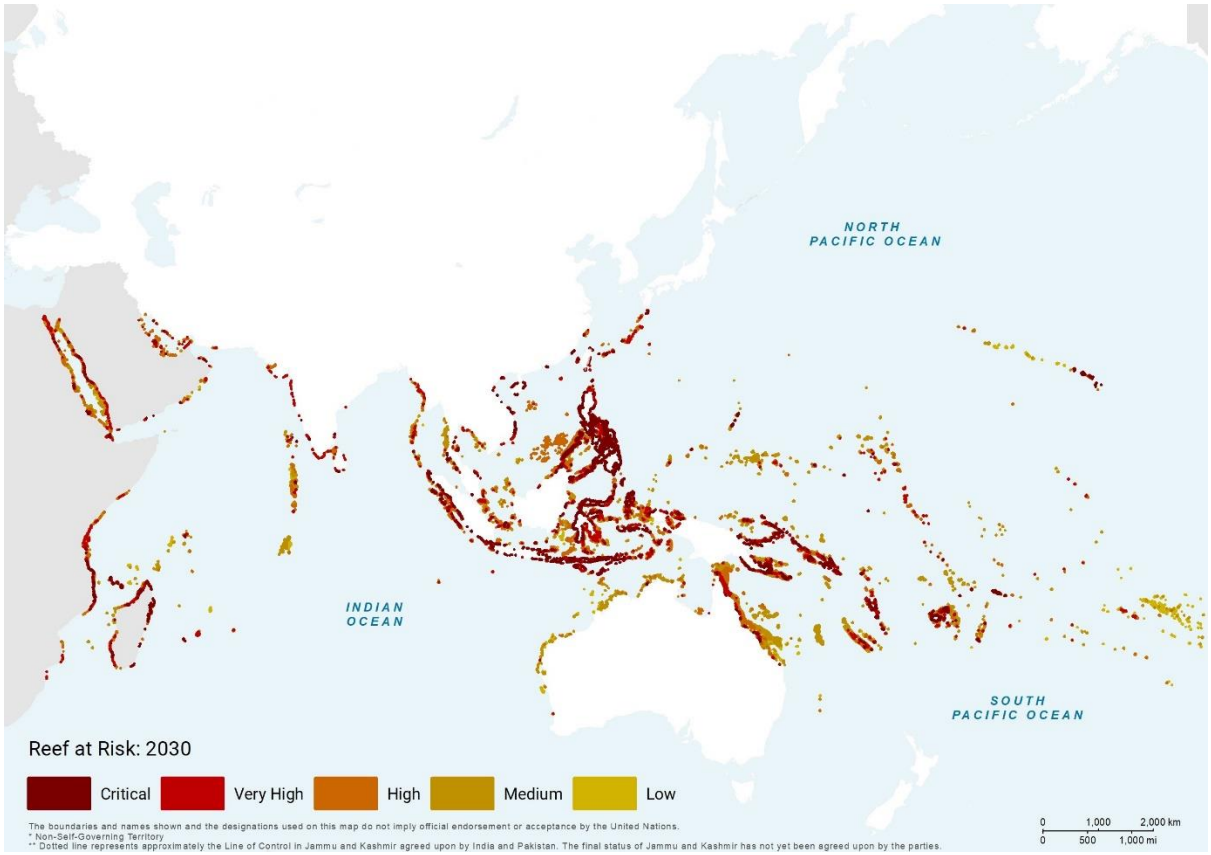

Figure 9 Distribution of categories of coral reefs at risk from the integrated local and global threats projected from 2030 in the Asia Pacific region (Burke et al., 2011).
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, and damage, Overfishing and destructive fishing. Global threats covered Thermal stress (warming sea temperatures, which can induce coral bleaching) and Ocean acidification (driven by increased CO2, which can reduce coral growth rates) (Burke et al., 2011).
The distribution of coral reefs at risk in the current scenario and projected scenario in 2050 is provided in the Annex (Annex IV: Maps of Distribution of Coral Reefs at Risk in the Asia Pacific).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

Possible Causes of Risk to the Coral Reefs Ecosystem

Coral reefs are facing serious challenges from human-induced local threats including overfishing, destructive fishing, coastal development, agricultural runoff, shipping, watershed-based pollution, or marine-based pollution and damage. Climate change, when combined with local threats, exacerbates the degradation of coral reefs. Climate change is causing coral reefs to bleach and acidify, making them more susceptible to damage from storms, infestations, and diseases. Rising sea surface temperatures are causing coral bleaching, which is when corals lose their colourful algae, turn white and expose skeletons (Burke et al., 2011). This is projected to intensify in the coming decades (Souter et al., 2020). Ocean acidification is also a threat to coral reefs. It makes it harder for corals to grow and maintain their structure (Burke et al., 2011), and increases the sensitivity of corals to rising sea surface temperature (Albright et al., 2016). Sea level rise (SLR) can cause coral reefs to lose elevation leading to increased

inundation and wave exposure, which can damage the reef. Despite the vertical adjustment, and ability to grow vertically to keep up with sea level rise (Cahoon et al., 2019; IPCC, 2022a), if the rate of SLR exceeds the rate of reef growth, the reef can be submerged and lost. The areal extent of the reef can expand or contract depending on the rate of loss and the rate of new habitat formation (Saintilan et al., 2023). The degradation of coral reefs is typified by reduced areas of living coral, increased algal cover, reduced species diversity, and lower fish abundance (Souter et al., 2020). This is leading to the degradation of coral reefs, which are important ecosystems that provide food and shelter for marine life. Unfortunately, coral reefs are projected to experience increasing frequency of disease, bleaching, and death due to habitat loss, overfishing, pollution, sediments and nutrients from land run-off, sea level rise, ocean warming, and ocean acidification (IPBES, 2018).

Key Message

Asia Pacific is the Guardians of Coral Reefs, one-fourth of the global coral reefs, a $USD7.1 Trillion Global Treasure

In the Asia Pacific region, coral reefs cover a vast 20 million hectares, accounting for over 77% of the global coral reef area. The total estimated annual worth of coral reef services in the region reached a staggering US$7.1 trillion in 2019. Globally, the coral reef ecosystem is renowned for its invaluable ecological, economic, and social contributions, serving as one of the most diverse habitats and supporting approximately 25% of known marine species.

The region has lost a quarter of coral reefs in the last 15 years amid battling bleaching and extinction, a race against rising temperatures.

However, the region has faced a concerning 22% decline in average coral cover over the past 15 years, with an accelerated loss of 18.7% during the early 2010s to late 2010s, mainly attributed to rising sea surface temperatures, leading to widespread coral bleaching. A grave concern is that more than one-third of the coral reefs have already disappeared in the region, and projections indicate that the loss could escalate to 50-70% if the temperatures rise by 1.5°C.

Climate change and ocean acidification are the major drivers of the coral reef losses.

The primary threats to coral reefs are linked to global warming and ocean acidification, compounded by local anthropogenic pressures such as land-based and marine pollution, overfishing, and destructive fishing practices. Therefore, consistent monitoring of the coral reef ecosystem is imperative to mitigate these challenges and safeguard their crucial contributions to our planet.

Seagrass in the Asia Pacific

Seagrass, a beautiful marine flowering plant, is widely distributed along temperate and tropical coastlines of the world. There are more than 70 species of seagrass around the world, found in 159 countries on six continents, potentially covering over 30 million hectares, with more than 1 billion people living within 100 km of a seagrass meadow (UNEP, 2020). It is one of the most powerful coastal ecosystems that play a significant role in fishery production (Herrera et al., 2022), provides nursery area to nearby salt marshes, shellfish beds, coral reefs and mangrove forests, habitats sediment stabilization, water purification, broader ocean functionalities and helps fight climate change and protect coastal communities (Duarte et al., 2008; McKenzie et al., 2021, 2020; Spalding et al., 2003; UNEP, 2020).

Dynamics of Seagrass Changes

Around a quarter of the world's seagrass meadows are found in the Asia-Pacific region, covering an estimated area of 14.92 million hectares (UNEP-WCMC and Short, 2021), providing an estimated US$432 billion worth of ecosystem services annually (Costanza et al., 2014). The seagrass ecosystems in the Asia-Pacific region are distributed across four of the six biogeographic regions of the world: the Tropical Indo-Pacific, Temperate North Pacific, Mediterranean, and Temperate Southern Oceans (Figure 10). The Tropical Indo-Pacific region (East Africa, South Asia, and tropical Australia to the eastern Pacific) is the largest and highest diversity biogeographic supporting 24 tropical seagrass species. The temperate North Pacific (Korea to Baja, Mexico) supports a high diversity of temperate seagrass species in estuaries, lagoons, and coastal surf zones. Temperate Southern Oceans (New Zealand and temperate Australia, South America, and South Africa) regions are characterized by extensive meadows supporting 18 temperate seagrasses with low-to-high diversity often growing under extreme conditions. The Mediterranean (including the Mediterranean Sea, the Black, Caspian and Aral Seas and northwest Africa) bioregion is characterized by vast deep seagrass meadows with moderate diversity of temperate/tropical species growing in clear water (Short et al., 2007). While hosting some of the world's most diverse seagrass ecosystems, the Asia-Pacific region remains the least explored area in terms of trade-offs and/or synergies between seagrasses and fishing activities, contributing only 6% to the overall global count of the studies (Herrera et al., 2022; IPBES, 2018).

Despite its low diversity, seagrass meadows support a high level of marine biodiversity (Short et al., 2007). Seagrass is a critical component of the diets of coastal communities, providing a significant portion of their protein needs. Annually, seagrass ecosystems deliver approximately US$28,916 in ecosystem services per hectare (Costanza et al., 2014), and with a worldwide seagrass extent of around 66.7 million hectares (Green and Short, 2003; OSPAR, 2015; Telesca et al., 2015; UNEP-WCMC and Short, 2021), this accumulates to an estimated total value of roughly US$1.93 trillion per year. According to a recent report from the UNEP, the estimated annual ecosystem services value of 30 million hectares of seagrass is around US$868 billion per year (UNEP, 2020). There is another estimate of aggregated global flow value of US$6.8 trillion per year from 234 million hectares area of seagrass/algal beds (Costanza et al., 2014).

Other studies reported the global seagrass area ranging from 17 to 60 million ha (Duarte et al., 2010; Green and Short, 2003; UNEP-WCMC and Short, 2021), and a moderate to high confidence estimates of 16 to 26.6 million hectares (McKenzie et al., 2021, 2020).

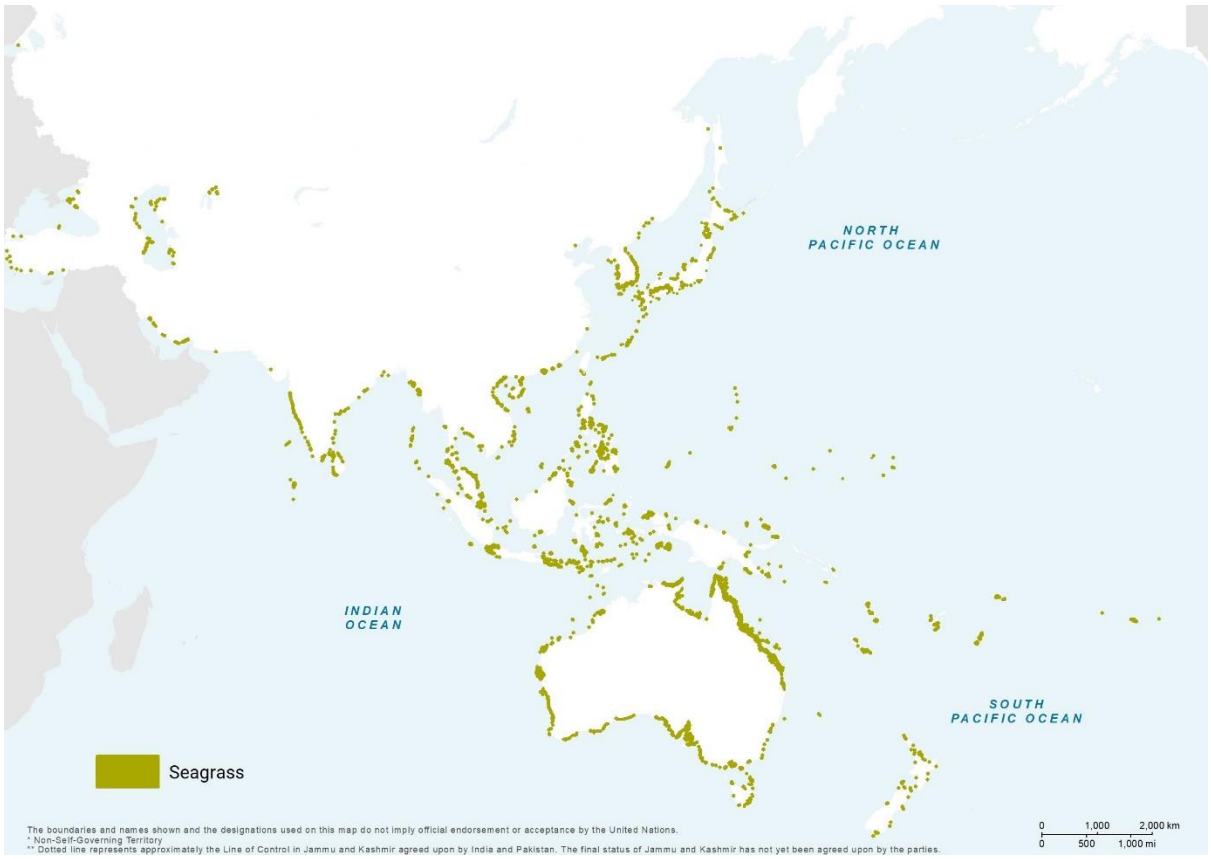

Figure 10 Distribution of seagrass in the Asia Pacific region
The dataset is extracted from the Global distribution of seagrasses (version 7.1). Seventh update to the data layer used in (Green and Short, 2003)(UNEP-WCMC and Short, 2021). *The map shows both the sighting spots (points) and the marked areas (polygons) of seagrass. Our estimates of the area covered by the seagrass in the Asia Pacific are based on the mapped area of seagrass* (UNEP-WCMC and Short, 2021).
Source: Author's compilation from the sources mentioned above

An analysis of temporal variations in seagrass bed area across 68 sites in nine different countries/territories in the region revealed some concerning trends (Table 6). More than 60% of these seagrass beds experienced a decline, with an average annual rate of 10.9%. Conversely, 20% of the beds saw an increase in size, with an average annual growth rate of 8.1%. This resulted in an overall average decline of 4.7% per year (Sudo et al., 2021).

The drivers of these changes were diverse and included a range of human-induced threats. These threats encompassed activities like coastal development, fisheries, and aquaculture, along with natural factors such as typhoons and tsunamis. These findings underscore the complex interplay of environmental and anthropogenic factors affecting seagrass bed dynamics in the region (Sudo et al., 2021).

Table 6 Temporal trends and changes (percentage rate of change) for seagrass beds in the Southeast Asia

Category	Recorded Samples		Rate of Change	
	Number of Samples	Relative Proportion (%)	Mean (%)	±SE
Declining	44	64.7	-10.9	2.6
Increasing	14	20.6	8.1	2.2
Stable	10	14.7	0	0.1
Overall	68	100	-4.7	2

Source: Author's compilation from (Sudo et al., 2021)

Seagrasses are the only submerged marine plants with an underground root and rhizome system. Seagrass below-ground biomass can equal that of above-ground biomass and is often much higher. The mean above- and below-ground biomass of seagrass were very similar, 223.9±17.5 and 237.4±28 g dry weight/ m^2 (Duarte and Chiscano, 1999). Another study suggested a median biomass of seagrass to be 205 g dry weight / m^2, above- and below-ground biomass combined (Spalding et al., 2003). The net primary productivity of seagrass is 1012 g dry weight / m^2 / year. This high productivity and biomass of seagrass signifies its value and proportion in coastal ecosystems providing services to humans (Duarte and Chiscano, 1999; Spalding et al., 2003).

Assessing the status and trends in global distribution is a challenging and complex task due to the wide range of species diversity patterns, many documented areas, and the dynamic nature of seagrass habitat (UNEP, 2020). There is hardly any global or regional assessment of the dynamics of seagrass. Therefore, it is difficult to estimate systematic loss and gain in regional seagrass cover. Over the past 50 years, 30 % of global seagrass areas have been lost (Saenger et al., 2013). Several studies have documented significant losses of seagrass in Oceania and Southeast Asia. The rate of decline is over 20% in some areas, such as Viet Nam and the Philippines (Seddon et al., 2000). In Japan, there has been a significant decrease in seagrass beds in temperate regions over the past 30 years (Yamakita et al., 2011). This decline is due to a combination of human activities, natural disasters such as typhoons, storms, tsunamis, and climate change (Duarte et al., 2008).

Seagrass meadows store vast amounts of carbon, an important nature-based solution.

Seagrass meadows provide powerful nature-based solutions to mitigate climate change (NSF, 2012). They cover a tiny fraction of the ocean floor, but they store up to 18% of the world's oceanic carbon. Seagrasses absorb large amounts of carbon dioxide from the atmosphere and store it in the ocean. They also protect the coast from erosion caused by storms (IPBES, 2018). Another study has suggested that even though seagrass meadows cover less than 0.2 % of the Earth's oceans, they play a significant role in burying carbon, accounting for over 10 % of the total carbon annually sequestered in the ocean. The global carbon reservoir within seagrass beds has been estimated to be as substantial as 19.9 billion tons (NSF, 2012).

Seagrass meadows are very efficient at storing carbon, up to 40 times more efficient than land forests (Fourqurean et al., 2012; McLeod et al., 2011; Serrano et al., 2021). One hectare of

seagrass can store up to 140 Mg of carbon (Pendleton et al., 2012; Serrano et al., 2021), or 512 Mg of carbon dioxide equivalent. The 14.92 million hectares of seagrass in the Asia Pacific region (UNEP-WCMC and Short, 2021) store about 2.088 gigatons of carbon, or 7.67 gigatons of carbon dioxide equivalent.

Some studies suggest that the seagrass beds can store up to 830 Mg of Carbon per ha, which is more than twice the amount of carbon that can be stored in a typical terrestrial forest - a typical terrestrial forest stores about 300 Mg Carbon per ha (NSF, 2012). However, seagrass beds are also vulnerable to disturbance, and they can release significant amounts of carbon dioxide if they are disturbed. It is estimated that 0.15 Pg of CO2 is released annually from disturbed seagrass ecosystems, which is equivalent to 3% of the annual carbon dioxide emissions from deforestation globally (Pendleton et al., 2012; Serrano et al., 2021).

In the Asia Pacific, with the estimate cover of 14.92 Mha seagrass bed, and 1.5% annual degradation or conversion rate and 326 Mg CO2 emission per ha, the estimated amount of annual CO2 emission from ecosystem degradation could be approximately 0.072 Pg. This might be equivalent to 1.5 % of the annual carbon dioxide emissions from deforestation globally (Pendleton et al., 2012; Serrano et al., 2021)However, these emissions could be changed due to different estimates of all three factors including estimate area of seagrasses, the rate of conversion or ecosystem degradation, and annual carbon emissions.

Seagrass Ecosystem Services

Seagrasses are highly valuable coastal and marine ecosystems with significant ecological, economic, and social benefits. They play a critical role in supporting biodiversity and serve as essential nurseries for commercially important fish, bivalves, and crustaceans. Seagrass meadows are rich in marine life, including protected species like dugongs, sea turtles, sharks, and seahorses. Additionally, seagrasses contribute to climate regulation by storing substantial amounts of carbon in their biomass and sediment, aiding in mitigating climate change. They also act as a buffer against ocean acidification by releasing oxygen and removing carbon dioxide from seawater during daylight hours. Moreover, seagrasses offer coastal protection, preventing erosion and shielding against flooding and storm surges. Lastly, they provide cultural services, fostering a sense of identity for local communities and offering opportunities for recreational activities such as birdwatching, diving, and fishing (UNEP, 2020).

Seagrass ecosystems in Australia, outperform other coastal ecosystems, such as mangroves, in terms of per-hectare abundance, biomass, and economic benefits. Specifically, a single hectare of seagrass supported an additional 55,000 fish annually compared to bare seabed, resulting in an extra biomass of 4,000 kg and a yearly economic value increase of US$1400 (Jänes et al., 2020).

Seagrass ecosystems are worth trillions of dollars each year. Each hectare of seagrass provides approximately US$28,916 in ecosystem services, such as filtering water, providing habitat for fish, and protecting coasts from erosion (Costanza et al., 2014). The global coverage of seagrass is estimated to be between 30 and 66.7 million hectares (Duarte et al., 2010; Green and Short,

2003; UNEP-WCMC and Short, 2021). This means that seagrass ecosystems provide an estimated US$1.93 trillion to US$868 billion in ecosystem services annually.

Seagrass at Risk

The survival of this seagrass ecosystem is under threat due to unprecedented coastal development and population growth, increasing pollution, and the impacts of climate change (UNEP, 2020). Seagrass in the Asia Pacific region is under threat; however, the drivers and intensity of threats vary across the region. Such as, Southeast Asia is the global centre of seagrass biodiversity, but human activities such as mining, deforestation, and agriculture are negatively impacting seagrass beds In Australia, which has the most seagrass species in the world, seagrass loss is severe in industrialized parts of the coast due to shoreline hardening, land reclamation, and fisheries. seagrasses in India are threatened by human activities such as deforestation, mangrove destruction, shoreline construction, storms, vessel traffic, and sewage disposal (UNEP, 2020). Overall, there are limited studies on mapping of spatial distribution and trends of seagrass habitat in the Asia Pacific region. It is important to continue monitoring seagrass populations and to take steps to protect them (Short et al., 2011).

The status of seagrass species in the Asia Pacific is mixed, with some regions having high species diversity and others having high levels of threat (Figure 11). However, seagrasses in the region are facing several threats, including habitat loss, pollution, and climate change. The highest concentration of declining seagrass species is in China, Korea, and Japan, where most seagrass species are endangered, and vulnerable, and 80–100% of all seagrass species are in decline. with up to 100% of species in some areas of China, Korea, and Japan in threatened or Near Threatened categories due to heavily developed coasts with extensive shoreline reclamation (Green and Short, 2003). The Coral Triangle, a marine area located in the western Pacific Ocean including the waters of Indonesia, Malaysia, the Philippines, Papua New Guinea, Timor Leste, and Solomon Islands, has the highest seagrass species diversity in the Asia Pacific. In Southeast Asia, several species of Least Concern are in decline because of aquaculture, artisanal fisheries, and heavy watershed siltation. The Indo-Pacific region (Short et al., 2007) is categorised with declining trends in seagrass species. The declining trends in the region are higher in coastal areas of southern Australia and south Asia. The Tropical Indo-Pacific bioregion has the highest percentage of species where trends in population are unknown (24%) (Short et al., 2011).

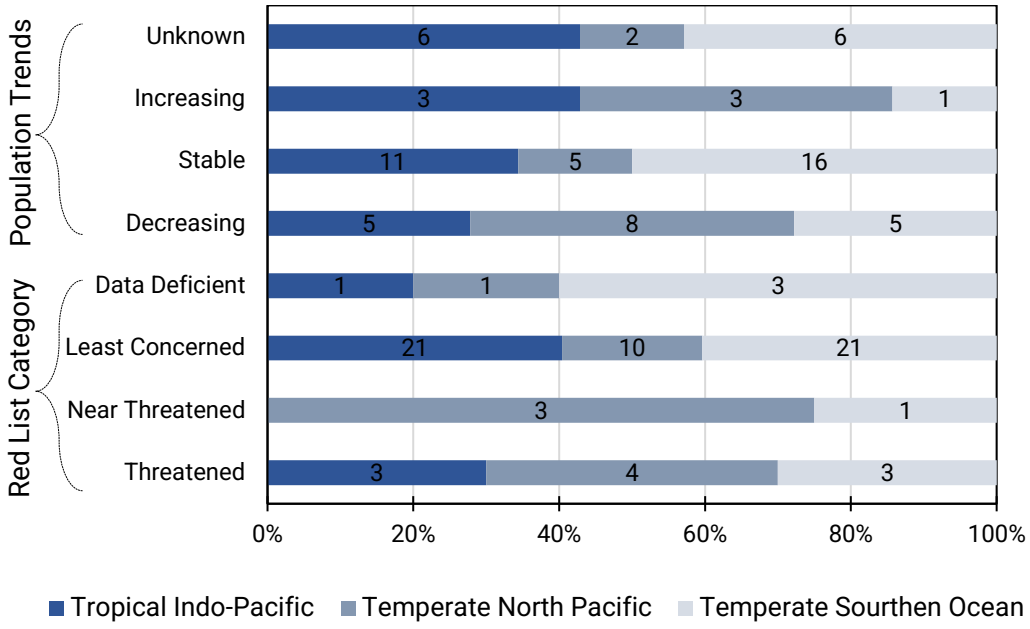

Figure 11 Number and proportion of seagrass species for each Red List Category and population trends (Short et al., 2011) in the bioregions (Short et al., 2007) encompassing the distribution of the seagrasses in the Asia Pacific region.

Depletion of the seagrass ecosystem could **release enormous CO2** into the atmosphere as the seagrass is one of the most efficient carbon sinks. The diminished ability of seagrasses to capture and retain carbon is a matter of great concern, as the depletion of seagrass resources ultimately results in substantial emissions of CO2 into the atmosphere (Arias-Ortiz et al., 2018). For instance, a notable example is Shark Bay in Australia, one of the world's largest seagrass ecosystems, which suffered damage during a marine heatwave in 2010/2011. This event led to the release of an estimated 2–9 million tons of CO2 into the atmosphere and contributed to the decline of species associated with seagrass ecosystems, many of which are of conservation importance or commercially targeted (UNEP, 2020).

Possible Causes of Risks to Seagrass Ecosystem

Seagrasses face various threats, including water pollution, climate change, coastal development, overfishing, boat-related damage, diseases, invasive species, ocean acidification, sea level rise, and habitat destruction (UNEP, 2020). Seagrass meadows are important ecosystems that are threatened by both **natural and human-caused stressors**. The biggest threat to seagrass is now human population growth, leading to increased human-made pollution in the coastal waters (*Figure 12*), which is the main reason why seagrass is declining worldwide (Short and Wyllie-Echeverria, 1996). The major threat to the future of seagrass ecosystems is **synergistic effects** when human-caused disturbances interact with climate-induced changes in ways that make them even more damaging. For example, climate change is increasing precipitation, which leads to more runoff of nutrients and silt from land. This runoff is partly caused by changes in land use, such as deforestation and agriculture (Duarte et al., 2008). The

combination of these factors is a major threat to the distribution and health of seagrass beds. Threats to seagrass ecosystems can vary in their spatial and temporal scales and intensities. When multiple threats occur together, they can interact in ways that make them more damaging. However, there is currently little quantitative understanding of these interactions to plan appropriate management plans (Griffiths et al., 2020).

The primary cause of seagrass loss is reduced water clarity due to increasing nutrient loading and turbidity. Both nutrient loading and turbidity can reduce the amount of light that reaches seagrass beds, which is essential for seagrass growth and development. Other factors that contribute to nutrient loading and turbidity include fertilizer runoff from agriculture, sewage discharge, industrial waste, and coastal development (Short and Wyllie-Echeverria, 1996). In Southeast Asia, sediment flow to the coastal waters is the major threat to seagrass ecosystems, and the primary cause of increased sediment flow is deforestation in the watersheds (FAO, 2020). Other direct human impacts of the threat to seagrass habitat include fishing and aquaculture, introduction of exotic species, boating and anchoring, and development-related changes in the coastal habitats (UNEP, 2020).

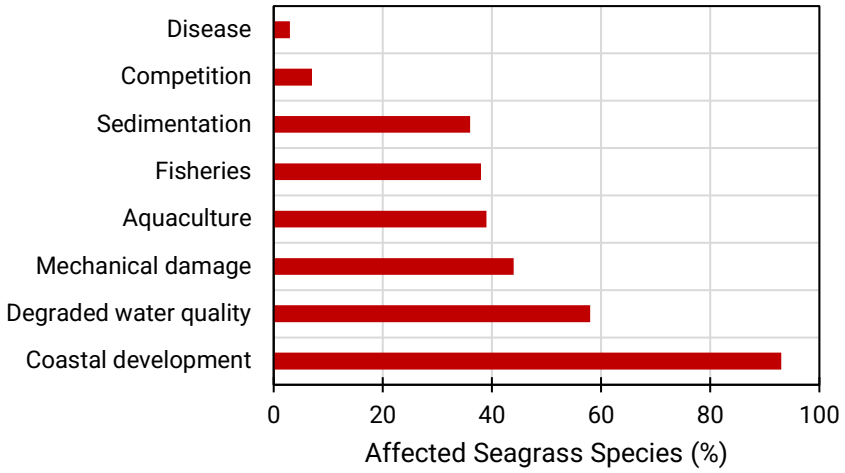

Figure 12 Seagrass species (proportion of 72 species) affected by the major threat category due the direct human impacts (Short et al., 2011)

Climate-induced impacts that could significantly affect the growth and distribution of seagrasses include global warming, sea level rise, heatwaves, precipitation, increase in atmospheric and oceanic carbon dioxide, and the rising frequency and intensity of storms. **Rising global temperatures** affect various aspects of seagrass metabolism, growth, reproduction, and spatial distribution patterns of seagrass. Progressively increasing temperatures could be a major threat to local seagrass populations, especially those that live near the low-latitude borders of their distribution (Spalding et al., 2003). **Rising sea levels** will affect water circulation, tides, currents, salinity, coastal erosion, and water clarity, all of which could have a major negative impact on the performance of local seagrass populations (Short and Neckles, 1999; Spalding et al., 2003). **Storms** can destroy seagrass beds by reducing light availability and uprooting plants, opening space for other, faster-growing species to colonize.

The effects of storms can vary spatially and temporally, across seagrass beds, but storms can exacerbate the threat to seagrasses that are already under stress from other factors (Duarte et al., 2008).

Key Message

Seagrass is a powerhouse of carbon sequestration

Seagrass meadows are pivotal in climate change mitigation through nature-based solutions. Although they occupy a small portion of the ocean floor, seagrasses play a significant role in carbon storage, accounting for up to 18% of the world's oceanic carbon. These underwater plants efficiently absorb carbon dioxide from the atmosphere and sequester it in the ocean., The Asia-Pacific region hosts vast seagrass areas spanning approximately 14.92 million hectares, a quarter of the world's seagrass hosting the world's most diverse seagrass ecosystems. These meadows collectively store an impressive 2.088 gigatons of carbon (equivalent to 7.67 gigatons of CO2) and provide ecosystem services valued at approximately US$432 billion annually.

Asia Pacific's Seagrass is declining and less explored - a hidden diversity worth discovering.

Despite the immense ecological diversity of seagrass ecosystems in the region, they have been relatively underexplored, and numerous studies have documented significant losses, particularly in Oceania and Southeast Asia, where some areas have experienced a decline of over 20%, such as Viet Nam and the Philippines. These declines are primarily attributed to various human-induced threats, including coastal development, fisheries, and aquaculture, as well as extreme climate events.

Imperative to protect seagrass ecosystems to prevent Disruption to Avert Carbon Release

Seagrass beds, while offering substantial carbon storage benefits, can also release significant carbon when disturbed, emitting approximately 0.72 Pg of CO2 annually from the Asia Pacific seagrass ecosystems (at a rate of 326 Mg per ha. This emission may be equivalent to 1.5% of the annual global CO2 emissions from deforestation. The preservation of seagrass ecosystems is vital, and the establishment of carbon credit markets for their protection is imperative, considering the diverse services these ecosystems provide.

Chapter 2: Milestone Thresholds for Action on Coastal Nature-based Solutions

This chapter sums up the losses, risks, and resilience of coastal ecosystem services to set milestone thresholds for actions for nature-based solutions and highlight the priority area for landscape restoration in the Asia-Pacific region. This information will be used to identify priority areas for landscape and coastal restoration from the perspective of both carbon mitigation and enhancing climate resilience. There are efforts underway to establish incentives aimed at promoting the protection and restoration of coastal ecosystems. These initiatives aim to counteract centuries of decline, reduce the rate of mangrove loss, and showcase the potential for revitalizing coastal ecosystems that have been adversely affected by human activities in the coastal zone (Saintilan et al., 2023).

Conservation and Restoration of Mangroves

The Asia Pacific region has the highest restoration potential due to the massive deforestation. At the national level, Indonesia had the largest potential restoration area, with over 2,000 km2 available for restoration which is one-fourth of the area with restoration potential across the globe (Leal and Spalding, 2022; UNEP, 2023a). This entails addressing both biophysical aspects, such as water quality and sediment availability, and social aspects, including land tenure and resource access, to ensure successful restoration outcomes (FAO, 2023). A detail discussion on the dynamics of mangroves and adaptation measures in the region is made in the Annex (Annex II: Dynamics of Mangroves Restoration in the Region)

The Global Mangrove Alliance (Leal and Spalding, 2022) has set a revised goal for 2030, focused on securing the future of mangroves and the communities reliant on them. This goal can be summarized in six words: Prevent Loss (eliminate mangrove loss from direct human activities); Restore Half (reestablish mangroves to cover at least half of recent losses); and Double Protection (increase long-term safeguarding of remaining mangroves by another 40%). Based on this goal, the milestone thresholds' area for reducing losses, recovering losses, and protect existing mangroves in the ESCAP is calculated (**Error! Reference source not found.**,

Reduce Losses	Area	Carbon	CO2	Fish Production	Ecosystem Services
	(km2)	(Mt)	(Mt)	(US$ billion)	(US$ billion)
Losses 2010-2020	420	17.6	65.1	2.56	8.14
Direct Human Losses (62%)	260	10.9	40.4	1.59	5.05
70 % Reduction in Losses by 2030	182	7.7	28.3	1.11	3.53
80 % Reduction in Losses by 2030	208	8.7	32.3	1.27	4.04
90 % Reduction in Losses by 2030	234	9.8	36.3	1.43	4.54
100 % Reduction in Losses by 2030	260	10.9	40.4	1.59	5.05
Recover Losses					
Losses 1996-2020	3338	140.2	517.4	20.36	64.70
Recoverable (70%)	2337	98.1	362.2	14.25	45.29
50 % Recover Losses by 2030	1168	49.1	181.1	7.13	22.65
70 % Recover Losses by 2030	1636	68.7	253.5	9.98	31.71

90 % Recover Losses by 2030	2103	88.3	326.0	12.83	40.76
100 % Recover Losses by 2030	2337	98.1	362.2	14.25	45.29
Protection of Existing Mangroves					
Mangroves 2020	74808	3141.9	11595.2	456.33	1450.10
Estimate Protected Mangrove (40%)	29923	1256.8	4638.1	182.53	580.04
10 % more Protection Target by 2030	7481	314.2	1159.5	45.63	145.01
20 % more Protection Target by 2030	14962	628.4	2319.0	91.27	290.02
40 % more Protection Target by 2030	29923	1256.8	4638.1	182.53	580.04
60 % more Protection Target by 2030	44885	1885.2	6957.1	273.80	870.06

*C - CO2 Conversion Factor is 3.67 (IPCC, 2007), Fish production and ecosystem services area annual.

Refer to the sections below for the methods of calculating the "reduction in losses", "recover losses", and "Protection of existing mangroves".
The annual ecosystem services were estimated using the values provided by (Costanza et al., 2014), and annual fish production and carbon gain were calculated using estimates from (Leal and Spalding, 2022).

, Table 9, Figure 13, Figure 14) from the mangroves cover estimates in the region (Table 1, Table 3).

Reduce Losses	Area	Carbon	CO2	Fish Production	Ecosystem Services
	(km2)	(Mt)	(Mt)	(US$ billion)	(US$ billion)
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The annual ecosystem services were estimated using the values provided by (Costanza et al., 2014), and annual fish production and carbon gain were calculated using estimates from (Leal and Spalding, 2022).

Table 7 Targets of mangroves restoration by reducing current losses, recovering lost mangroves area and enhanced protection of the existing mangroves in the Asia Pacific. These targets are based on the net gain/loss of mangroves, the target could change if extracted from actual losses instead of net losses.*
These estimates for 70% reduction in losses, 50% restore losses, and 40% addtinoal proection of mangroves in the region. Also see . Also see

Reduce Losses	Area	Carbon	CO2	Fish Production	Ecosystem Services
	(km2)	(Mt)	(Mt)	(US$ billion)	(US$ billion)
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and Table 9

Reduction in Losses		**Recover Losses**		**Protection of Existing Mangroves**	
(km2)		(km2)		(km2)	
Losses 2010-2020	420	Losses 1996-2020	3338	Mangroves 2020	74808
Direct Human Losses (62%)	260	Recoverable (70%)	2337	Protection 40%	30000
Reduce Direct Human Losses Target by 2030 (70%)	182	Recovery Target by 2030 (50%)	1168	Protection Target by 2030 (40%)	30000

** Refer to the sections below for the methods of calculating the "reduction in losses", "recover losses", and "Protection of existing mangroves".*
Table 8. Ecosystem services from the different scenarios of milsstone thresholds for reduction in lossses, restoration of losses, and protection of mangroves in the Asia Pacific.

Reduce Losses	Area	Carbon	CO2	Fish Production	Ecosystem Services
	(km2)	(Mt)	(Mt)	(US$ billion)	(US$ billion)
Losses 2010-2020	420	17.6	65.1	2.56	8.14
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Refer to the sections below for the methods of calculating the "reduction in losses", "recover losses", and "Protection of existing mangroves".
The annual ecosystem services were estimated using the values provided by (Costanza et al., 2014), and annual fish production and carbon gain were calculated using estimates from (Leal and Spalding, 2022).

It is worth noting that the ecosystem services expected from the mangroves cover could vary due to a range of factors including the estimates of per hectare costs and growing stages of mangroves especially recovered mangrove areas will go through a gradient of succession from seedling to mature secondary forest to primary forests which may take several year to the fully functional forest ecosystem. Therefore, reduction of expected losses and protection of existing mangroves is the preferred way to avoid releasing stored carbon and sequester more carbon from the atmosphere. Moreover, national milestones for mangrove restoration may vary among countries in the region based on national polices, aspirations, and targets.

Reduction in Losses – Restore coverage and Slow Losses in the Asia Pacific

Mangrove loss has slowed significantly in recent years, providing an opportunity to stop all losses. Direct human-driven losses are targeted as these can be managed directly. It is estimated that human-driven losses account for 62% of total losses (Goldberg et al., 2020) (Leal and Spalding, 2022)*. Over the past decade, from 2010 to 2020, 420* km2 *of mangroves were lost in the Asia Pacific region (*Table 1*,* Table 3*), of which 260* km2 *(62%) could be attributed to the losses due to direct human impacts. To achieve zero direct human-driven mangrove loss, the loss rates should be gradually reduced. Assuming a linear reduction in human-driven losses, this strategy*

would save an estimated 182 km2 *of mangroves by 2030 in the Asia Pacific region* (Table 8, Table 9, Figure 13, Figure 14), a 43% reduction in the expected total mangrove losses (420 km2), or 70% reduction in the human-driven losses (260 km2) during 2024-2030 compared to the previous decade (Leal and Spalding, 2022). Since mangrove ecosystems can deliver approximately US$193,843 in ecosystem services per hectare per year (Costanza et al., 2014), the reduction of 182 km2 in mangroves loss could save a loss of ecosystem services worth US$ 3.53 billion per year in the long run. The Asia Pacific region would secure 0.0282 Gt of CO2). Halting an expected loss of 182 km2 will ensure commercially important fish and shellfish worth US$ 1.11 billion every year (Leal and Spalding, 2022).

Recoverable Losses - Restorable Mangroves Area in the Asia Pacific

In the Asia Pacific region, over 3,338 km2 of mangroves have been lost since 1996 (Table 1). It is estimated that 30% of the total mangrove losses are not restorable, as assessed for global mangrove losses (Leal and Spalding, 2022). Applying this rate to the Asia-Pacific region implies that 2,336 km2 of mangrove area lost between 1996 and 2020 is likely restorable in the Asia Pacific region. A reasonable target of half of this area, or 1,168 km2, could be included in a mangrove restoration goal for 2030.

The concentration of restorable mangrove areas is particularly high in Southeast Asia (Table 8, Table 9, Figure 13, Figure 14). This enables the prediction of the likely benefits of mangrove restoration in this region (Leal and Spalding, 2022). Since mangrove ecosystems can deliver approximately US$193,843 in ecosystem services per hectare per year (Costanza et al., 2014), the restoration of 1168 km2 could yield US$22.64 billion annually from the associated ecosystem services in the long run (Table 8, Table 9, Figure 13, Figure 14). The Asia Pacific region would secure 0.18104 Gt of carbon dioxide (CO2) equivalent and provide additional habitat which will generate over 7.135 billion commercially important fish and shellfish every year (Leal and Spalding, 2022). Various environmental factors that could impact the feasibility of restoration efforts, including variables like tidal levels, vulnerability to rising sea levels, and the connectedness of habitat patches, indicate that the most favourable conditions for restoration were primarily found in Southeast Asia and northern Australia in the Asia Pacific region (Leal and Spalding, 2022; Worthington and Spalding, 2018).

Protection of Existing Mangroves in the Asia Pacific

To prevent further mangrove loss, it is crucial to protect them through permanent conservation measures like national parks, reserves, or Other Effective Area-based Conservation Measures (OECMs). Even though not all unprotected mangroves are under immediate threat, safeguarding them through long-term commitments is essential. Studies indicate that safeguarding 40% (30000 km2) of mangroves in the Asia Pacific region would secure 4.65 Gt of carbon dioxide equivalent (CO2) and enhance commercial fish productivity worth US$143-183 billion annually (Leal and Spalding, 2022). Also see Table 8, Table 9, Figure 13, and

Figure 14. These preventive measures would save ecosystem services worth US$581.5 billion per year in the long run (Costanza et al., 2014). In conclusion, preserving mangroves sustainably is vital to prevent their loss and maintain their numerous benefits.

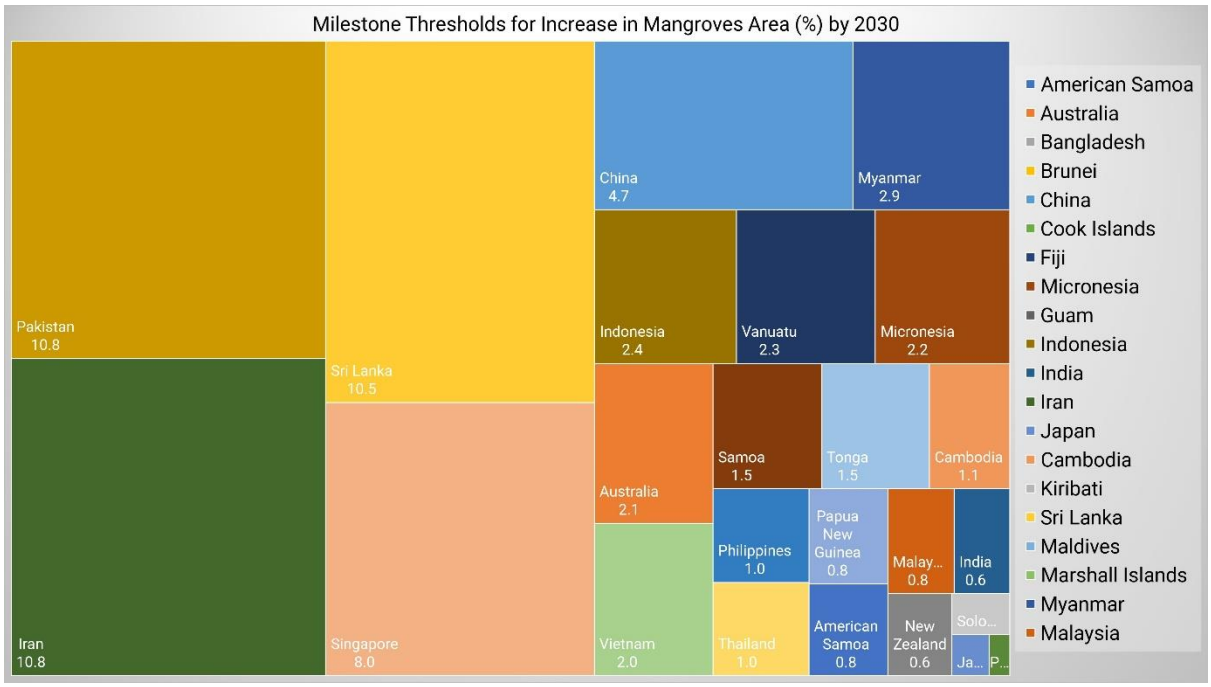

Figure 13 Distribution of target increase in mangrove area in the ESCAP countries by 2030, the target increase in area is estimated by adding "reduction in losses of expected losses by 2030", and "recoverable losses from the lost mangroves area during 1996 to 2020. Refer to sections above for the methods of calculating the "reduction in losses", "recover losses", and "Protection of existing mangroves"

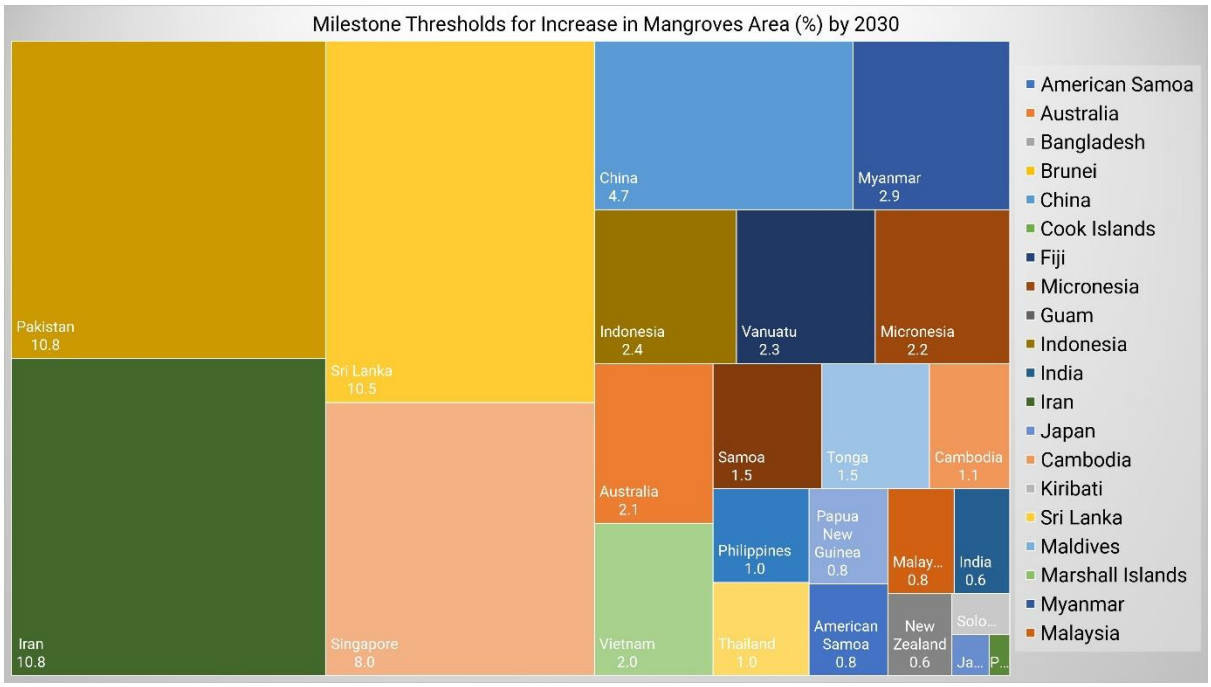

Figure 14 Distribution of target increase in the percentage of mangrove area in the ESCAP countries by 2030, the target increase in area is estimated by adding "reduction in losses of expected losses by 2030", "recoverable losses from the lost mangroves area during 1996 to 2020. Refer to sections above for the methods of calculating the "reduction in losses", "recoverable losses", and "Protection of existing mangroves

Table 9 Milstone thresholds for increase in mangrove area in the ESCAP countries from reduced losses, recovery of lost mangroves (1996 -2020), and protection of remaining mangroves. Refer to the sections above for the methods of calculating the "reduction in losses", "recover losses", and "Protection of existing mangroves"

Country	**Losses 2010-2020**	**Losses 1996-2020**	**Reduce Losses (2010-2020)**	**Recover Losses (1996-2020)**	**Protect Existing (2020)**	**Mangroves 2020**	**Target Mangroves Area by 2030**	**Target Increase (ha) in Mangroves Area by 2030**	**Target Increase (%) in Mangroves Area by 2030**
	A	B	C	D	E	F	E=C+D+F	G=C+D	H=(G/F)*100
American Samoa	-0.14	-0.55	0.06	0.19	12.82	32.05	32.30	0.25	0.8
Australia	-9175.68	-48391.26	3982.24	16936.94	406832.23	1017080.5	1037999.76	20919.18	2.1
Bangladesh	725.04	3668.63	0.00	0.00	179354.30	448385.75	448385.75	0.00	0.0
Brunei	14.66	34.96	0.00	0.00	4598.85	11497.12	11497.12	0.00	0.0
China	446.48	-2918.52	0.00	1021.48	8632.27	21580.66	22602.15	1021.48	4.7
Cook Islands	0.00	0.00	0.00	0.00	1.31	3.27	3.27	0.00	0.0
Fiji	42.73	241.95	0.00	0.00	19525.74	48814.35	48814.35	0.00	0.0
Micronesia	-222.25	-289.15	96.45	101.20	3517.77	8794.42	8992.08	197.66	2.2
Guam	0.38	0.38	0.00	0.00	20.89	52.21	52.21	0.00	0.0
Indonesia	-21466.44	-173903.84	9316.44	60866.34	1181359.37	2953398.4	3023581.20	70182	2.4
India	1288.35	-7333.94	0.00	2566.88	161513.85	403784.62	406351.50	2566.88	0.6
Iran	-291.93	-3092.42	126.70	1082.35	4470.66	11176.66	12385.70	1209.04	10.8
Japan	11.78	-4.87	0.00	1.71	412.45	1031.13	1032.84	1.71	0.2
Cambodia	638.64	-1963.90	0.00	687.36	25076.75	62691.88	63379.24	687.36	1.1
Kiribati	0.00	0.00	0.00	0.00	58.59	146.48	146.48	0.00	0.0
Sri Lanka	140.81	-5986.90	0.00	2095.41	7949.74	19874.35	21969.76	2095.41	10.5
Maldives	0.00	0.00	0.00	0.00	38.94	97.34	97.34	0.00	0.0
Marshall Islands	0.00	0.00	0.00	0.00	13.02	32.54	32.54	0.00	0.0
Myanmar	-4867.17	-38581.14	2112.35	13503.40	217415.73	543539.32	559155.07	15615.75	2.9
Malaysia	-3507.43	-6906.92	1522.22	2417.42	209829.91	524574.78	528514.42	3939.65	0.8
New Zealand	-389.33	581.07	168.97	0.00	11843.35	29608.38	29777.35	168.97	0.6
Pakistan	-6790.74	-17213.56	2947.18	6024.75	33115.45	82788.63	91760.56	8971.93	10.8
Philippines	3522.79	-7934.19	0.00	2776.97	113919.21	284798.01	287574.98	2776.97	1.0
Palau	-12.31	25.91	5.34	0.00	2275.09	5687.71	5693.06	5.34	0.1
Papua New Guinea	-4577.48	-4873.92	1986.63	1705.87	180989.49	452473.73	456166.23	3692.50	0.8
French Polynesia	5.45	2.98	0.00	0.00	50.08	125.20	125.20	0.00	0.0
Singapore	-44.81	-110.66	19.45	38.73	291.88	729.71	787.89	58.18	8.0
Solomon Islands	-247.68	-79.95	107.49	27.98	21060.23	52650.57	52786.05	135.47	0.3
Thailand	4823.41	-7020.00	0.00	2457.00	101119.45	252798.62	255255.62	2457.00	1.0
Tonga	-25.39	-12.09	11.02	4.23	417.24	1043.09	1058.34	15.25	1.5
Tuvalu	0.00	0.00	0.00	0.00	3.56	8.91	8.91	0.00	0.0
Viet Nam	-986.91	-9272.27	428.32	3245.29	74858.89	187147.22	190820.84	3673.61	2.0
Vanuatu	-52.85	-39.36	22.94	13.78	633.47	1583.67	1620.38	36.71	2.3
Samoa	-6.50	-1.77	2.82	0.62	92.87	232.18	235.62	3.44	1.5

Key Message

By 2030, there is the potential to restore 1,350 hectares of mangrove forests, aiming to mitigate 70% of recent losses due to direct human activities and recover 50% of past losses. This restoration effort could store around 209 million tons of CO2. Furthermore, by increasing the protection of 40% of existing mangroves in the Asia-Pacific, an impressive 4.65 billion tons of CO2 could be preserved, leading to a substantial annual boost in commercial fish productivity valued at USD 143-183 billion. Notably, Indonesia boasts the world's largest potential restoration area, emphasizing the need for supportive policies to facilitate mangrove restoration in the region.

Conservation and Restoration of Coral Reefs

Coral reefs at risk are important to protect. High-risk coral reef areas could be given conservation priority or immediate restoration if already degraded. For example, locations where coral reefs are at risk due to the combined impact of local and global stressors projected for 2030 (Figure 9) or 2050 (Figure 29). According to map-based indicators of coral reef health (Burke et al., 2011), 60% of coral reefs in the Asia-Pacific region will face high (34%), very high (17%), and critical (9%) threats from integrated local and global pressures by 2030 (Table 10). Immediate recovery plans should be devised for critically and very highly threatened coral reefs in the region. Since the coral reefs provide ecosystem services worth US$ 352,249 per hectare per year (Costanza et al., 2014), therefore, the conservation and restoration of the high-risk coral reefs could ensure ecosystem services of US$4.05 trillion (from 11.5 million ha of coral reefs by 2030) and US$5.14 trillion (from 14.6 million ha of coral reefs by 2050) (Table 10).

Table 10 Coral Reefs for conservation and restoration priorities based on the assessment of coral reefs at risk due to combined impacts of local and global threats. (Burke et al., 2011). The area is in million hectares. Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

	Threat Category	Recent Scenario		Scenario by 2030		Scenario by 2050	
		Area	%	Area	%	Area	%
Areas for Conservation Priority and Restoration	Critical	0.0	0.0	1.7	8.6	2.2	11.4
	Very High	1.9	9.6	3.2	16.5	3.8	19.9
	High	3.2	16.7	6.6	34.1	8.6	44.4
Area for Long-Term Conservation Plans	Medium	6.3	32.6	6.5	33.7	4.6	23.8
	Low	7.9	41.1	1.4	7.2	0.1	0.5

Of the various threats' reefs face as the climate changes, an increasing frequency and severity of coral bleaching is a major concern. By 2050, under the emission scenario RCP 4.5, 70% of the coral reefs in the Asia Pacific are projected to bleach twice in a decade (2X), and at least half of this could experience annual bleaching (10X) (Figure 15). Under the projection for emission scenario RCP 8.5, the situation could worsen, with 93% (2X) and 85% (10X) of reefs projected to bleach (Figure 15). The locations projected to experience annual bleaching sooner (Figure 16) may require urgent action to reduce anthropogenic stressors and support coral recovery, for instance, the hotspot area of coral reefs at risk from the integrated local threats (Figure 9, Figure 28, Figure 29), the local threats could be reduced by implementing effective nature-based policies. This is because bleaching events can weaken corals and make them more susceptible to other threats, such as disease and overfishing (Van Hooidonk et al., 2013).

Despite providing ecosystem services, worth 375 billion $US, human activities are threatening nearly 60% of the world's coral reefs (WRI, 1998). By 2050, most coral reefs around the world are expected to experience bleaching every year. Rising ocean temperatures and other stressors, such as pollution and overfishing, are putting coral reefs under stress. When stressed, corals expel their symbiotic algae, if bleached corals are not able to recover, they will die. Bleaching events are becoming more common and severe, and many governments are not prepared to respond (Van Hooidonk et al., 2013).

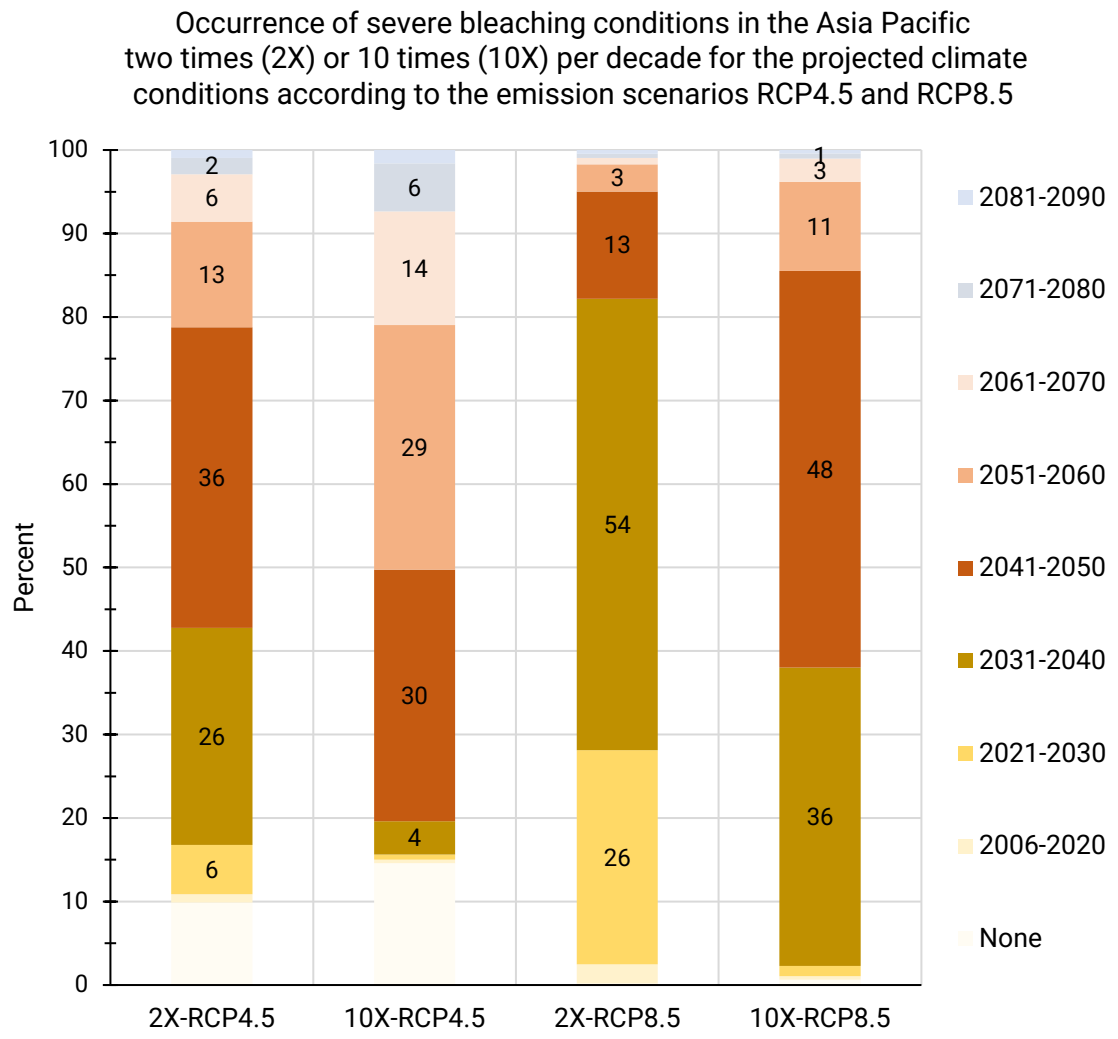

Figure 15 Occurrence of severe bleaching conditions in a decade in the Asia Pacific, two times (2X) or 10 times (10X) per decade for the projected climate conditions according to the emission scenarios RCP4.5 and RCP8.5.

Source: Authors compilation from *(van Hooidonk et al., 2015; Van Hooidonk et al., 2013)*, https://coralreefwatch.noaa.gov/climate/projections/downscaled_bleaching_4km/

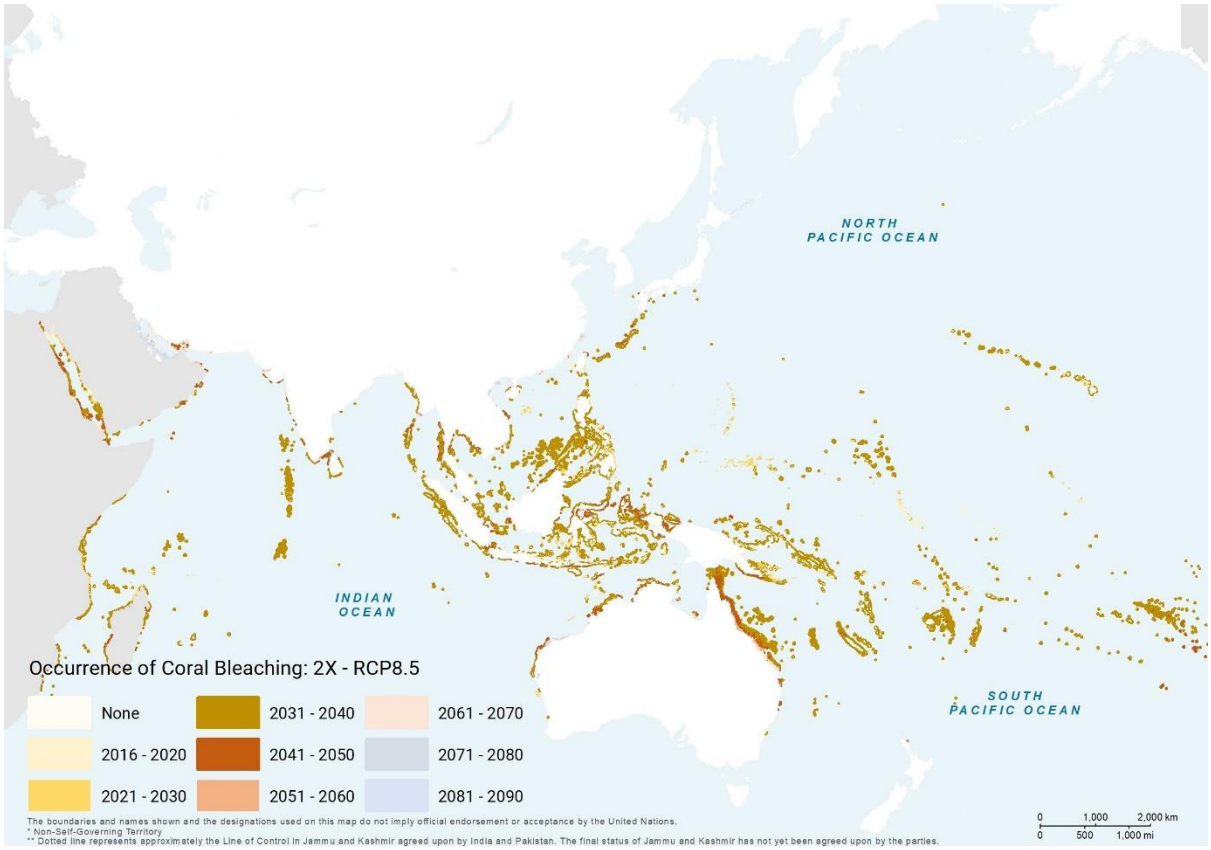

Figure 16 Spatial distribution of occurrence of severe bleaching of coral reefs in the Asia Pacific, 2X – RCP8.5, indicating two times (2X) occurrence of coral bleaching per decade for the projected climate conditions according to the emission scenarios RCP8.5
Source: Authors compilation from (van Hooidonk et al., 2015; Van Hooidonk et al., 2013), *https://coralreefwatch.noaa.gov/climate/projections/downscaled_bleaching_4km/*

Key Message

By the year 2030, most coral reefs in the Asia-Pacific region, specifically 60%, will be exposed to a range of significant threats, including high, very high, and critical levels, resulting from the combined impact of local and global stressors.

Among the various threats faced by coral reefs in the Asia Pacific, the increasing frequency and severity of coral bleaching is a pressing concern. By 2050, a significant portion of the region's coral reefs is projected to experience frequent bleaching events, particularly under emission scenario RCP 8.5, highlighting the urgency of addressing anthropogenic stressors and supporting coral recovery. Bleaching weakens corals, rendering them more susceptible to other threats, such as disease and overfishing.

Protecting at-risk coral reefs is of utmost importance, and high-risk areas should be prioritized for conservation and immediate restoration efforts. Locations facing the combined impact of local and global stressors by 2030 or 2050, as well as those with critical or very high threats to coral reefs, require urgent recovery plans. Given the substantial ecosystem services provided

by coral reefs, conserving and restoring high-risk areas could yield significant benefits, with a potential value of US$4.05 trillion by 2030 and US$5.14 trillion by 2050.

Conservation and Restoration of Seagrasses

Creating carbon credit markets for seagrass conservation and restoration projects could provide financial incentives to protect seagrass ecosystems. This is important because seagrass ecosystems provide many valuable services, including carbon storage, climate change mitigation and adaptation, and coastal habitat (Macreadie et al., 2019). This makes them a key component of climate change adaptation and mitigation efforts. This requires a systematic assessment of the key ecosystem services and coastal habitat in the region to aid conservation, management and restoration (IPBES, 2018).

A comprehensive analysis was conducted to assess the vulnerability of seagrass ecosystems to human impacts. This analysis involved comparing the locations where seagrass was observed with a metric known as the Combined Human Impact (CHI), as described in the works by Halpern et al. (Halpern et al., 2019, 2008a, 2008b). The purpose of this comparison was to gauge the extent to which seagrass ecosystems are exposed to both direct and indirect human influences. The findings of this analysis were grouped into five distinct risk categories (Table 11, Figure 17), each reflecting a different level of vulnerability: Critical (greater than 4), Very High (ranging from 3 to 4), High (ranging from 2 to 3), Medium (ranging from 1 to 2), and Low (less than 1). These categories were used to quantify and communicate the degree of risk that seagrass ecosystems face from the CHI. The risk categories may not remain static. They could change when specific stressors affecting seagrass ecosystems are considered. Additionally, it is advisable to periodically update this data to incorporate recent trends and patterns, as understanding of the interactions between seagrass and human impacts evolves. This will help ensure that conservation and management efforts are based on the most current and accurate information available.

In the Asia Pacific region, approximately 29% of seagrass areas are showing higher levels of combined human impact (Table 11, Figure 17), including 18% classified as "high," 9% as "very high," and 2% as "critical." These areas present an opportunity for targeted conservation and seagrass restoration efforts. These priority areas hold significant potential (Table 11, Figure 17), with the capacity to safeguard ecosystem services valued at approximately $US 1.118 trillion and the retention of 444 Mt of carbon (equivalent to roughly 1,630 Mt of CO2). Moreover, they contribute to ongoing nature-based solutions aimed at mitigating atmospheric CO2. Nevertheless, it’s important to note that further research is needed to provide updated insights into the current situation in the region.

It's important to understand that seagrass data is available in two distinct formats: polygon-marked areas and individual seagrass sightings (Table 11, Figure 17). When dealing with marked areas, the approximate extent of seagrass at risk can be estimated to determine corresponding conservation priorities. However, with individual seagrass sightings, only the level of Combined Human Impact (CHI) at each point could be estimated categories to gauge the overall threat level. Therefore, the ability to estimate ecosystem services and carbon storage is limited to the marked areas. This limitation may lead to underestimations, as a significant portion of the data is in point form, and the overall extent of seagrass bed areas is not precisely known.

Table 11 Seagrass priorities area for conservation and restoration potential based on the assessment of human impact on the seagrass.
Source: Authors compilation from the CHI (Halpern et al., 2019, 2008a, 2008b) and seagrass (UNEP-WCMC and Short, 2021)

Marked Area of Seagrass Beds (ha)						
Conservation / Restoration	**Category**	**Area (ha)**	%	Ecosystem Service (billion $US) @352249 per hectare (Costanza et al., 2014)	Carbon (Mt) @ 140 Mg Corg per ha (Pendleton et al., 2012; Serrano et al., 2021)	CO2 (Mt) @ 513.8 MgCO2 per ha (Pendleton et al., 2012; Serrano et al., 2021)
Target Area for Long-Term Conservation Plans	**Low**	4197280	38	1478.5	587.6	2156.6
	Medium	3808421	34	1341.5	533.2	1956.8
Target Areas for Conservation Priority and Restoration	**High**	1978088	18	696.8	276.9	1016.3
	Very High	980923	9	345.5	137.3	504.0
	Critical	213772	2	75.3	29.9	109.8
Sighting of Seagrass bed						
Target Area for Long-Term Conservation Plans	**Low**	1109	22			
	Medium	2485	50			
Target Areas for Conservation Priority and Restoration	**High**	814	16			
	Very High	395	8			
	Critical	181	4			

The mitigation of anticipated seagrass declines can only be achieved by increasing awareness of the imperative roles of the seagrass ecosystem (Duarte et al., 2008). Seagrasses, like mangroves and tidal saltmarshes, sequester and store more carbon per unit area than terrestrial forests but can be more difficult to protect and conserve due to their fragility and associated non-permanence risks. Efforts to map and quantify the carbon sequestration potential of seagrass meadows have been limited across the countries in question (Carbon Market Institute, 2021)

Seagrass restoration is a complex process that requires careful planning to identify spatio-temporal trends in seagrass meadows to inform future restoration Scientists use satellite images and other data to identify the best places to plant seagrass. In Western Port, Victoria, Australia, scientists have found that some seagrass has recovered since large-scale losses in 1983, but there are still some areas where seagrass has disappeared (Dalby et al., 2023).

Seagrasses encounter a range of challenges, including water pollution, the effects of climate change, coastal development, overfishing, harm from boats, diseases, invasive species, ocean acidification, rising sea levels, and habitat destruction. It is imperative to undertake conservation initiatives to protect these essential ecosystems and the advantages they offer (UNEP, 2020). Conservation efforts are crucial to safeguard these vital ecosystems and the benefits they provide. Protecting seagrass ecosystems requires a comprehensive approach that addresses multiple threats, including climate change. Climate change mitigation strategies for

seagrass ecosystems are still being developed. There is a lack of long-term data on seagrass trends It requires improved legislation, policies, and planning frameworks that consider the cumulative impacts of marine and land-based activities. It is important to include cumulative impacts in management frameworks (Griffiths et al., 2020).

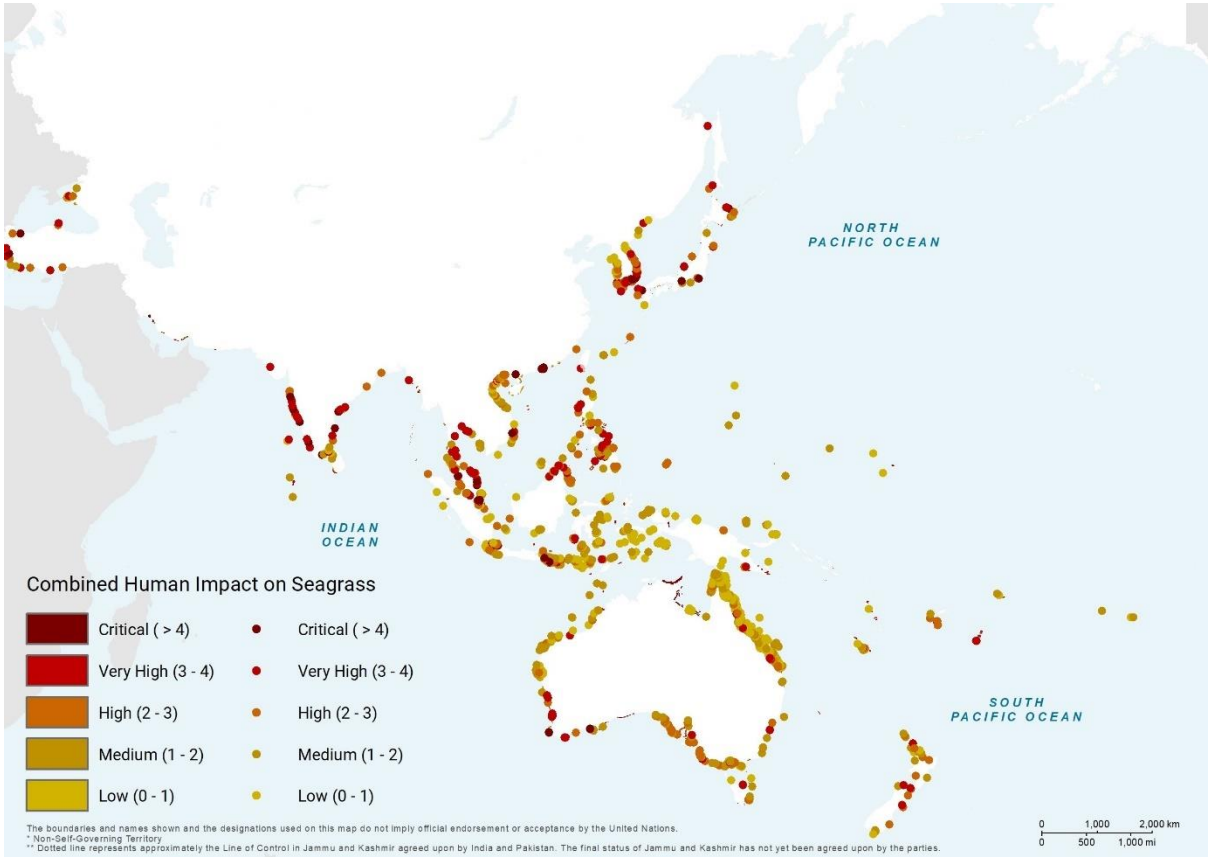

Figure 17 Distribution of seagrass with associated impact from the Combined Human Impact (CHI) in the Asia Pacific.
Source: Authors compilation from the CHI (Halpern et al., 2019, 2008a, 2008b) and seagrass (UNEP-WCMC and Short, 2021)

An overlay analysis of the seagrass sighting locations with the Combined Human Impact (CHI) on the marine ecosystems shows the exposure of the seagrass ecosystem to direct and indirect human impacts. Emissions from the loss of seagrass are estimated to contribute up to 299 Tg of carbon to the atmosphere per year. The diminished ability of seagrasses to capture and retain carbon is a matter of great concern, as the depletion of seagrass resources ultimately results in substantial emissions of CO2 into the atmosphere (Arias-Ortiz et al., 2018). For instance, a notable example is Shark Bay in Australia, one of the world's largest seagrass ecosystems, which suffered damage during a marine heatwave in 2010/2011. This event led to the release of an estimated 2–9 million tons of CO2 into the atmosphere and contributed to the decline of species associated with seagrass ecosystems, many of which are of conservation importance or commercially targeted (UNEP, 2020)

Seagrass is disappearing faster than it can grow back. By 2025, seagrass losses will be greater than they are now on all continents and oceanic islands. The extent of this loss will depend on whether we take immediate steps to eliminate the global threats to seagrass habitat.

Despite some increased awareness and protection, there is no sign that global losses of seagrasses will slow down in the next 20 years. Most of the impacts on seagrass ecosystems by 2025 will be from increasing human population densities, rather than climate change or sea-level rise.

Human impacts, particularly eutrophication and increased sedimentation, will continue to cause seagrass losses worldwide. Climate change is likely to have long-term, albeit small, impacts before 2025. Increased sea levels may not have a direct impact on seagrasses, but it may lead to losses in coastal areas that are already eroding, particularly those that are expected to experience more frequent storms.

Hardening of shorelines will also limit the ability of seagrasses to migrate inland to escape sea-level rise, reducing the amount of available habitat (UNEP, 2020).

Seagrass restoration is a complex and challenging task, but it is essential to protect and restore these vital ecosystems. By carefully selecting sites, using sustainable planting methods, and monitoring the results of restoration efforts, we can help reverse the decline of seagrass meadows worldwide (Duarte et al., 2008).

Key scientific methods for seagrass ecosystem restoration include a site selection model to identify suitable locations of protected areas with an ambitious target of 30% of the overall marine coastal areas, followed by a protocol to identify a sustainable source of planting stock, a reliable planting method, and most importantly a monitoring program to assess the outcome of the restoration (McKenzie et al., 2021).

More research is needed on seagrass-fishery interactions in tropical regions and on the socioeconomic aspects of these interactions. Future studies should also specify the fisheries management system that is in place. By improving the reporting of future studies, we can better understand and manage these important ecosystems(Herrera et al., 2022).

Key Message

Establishing carbon credit markets for seagrass conservation and restoration projects holds the potential to offer financial incentives for the protection of seagrass ecosystems, which are crucial contributors to carbon storage, climate change mitigation, adaptation, and coastal habitat preservation. This underscores their significance in the realm of climate change efforts. To effectively manage and conserve these ecosystems, a systematic assessment of their key ecosystem services and coastal habitat is essential. An analysis was conducted to evaluate the vulnerability of seagrass ecosystems to human impacts, categorizing them into five distinct risk levels based on their exposure to direct and indirect human influences. In the Asia Pacific region, approximately 29% of seagrass areas face higher combined human impact, with significant potential for targeted conservation and restoration, offering the opportunity to safeguard valuable ecosystem services (1.118 $US trillion), carbon storage (444 Mt of carbon - equivalent to roughly 1,630 Mt of CO2), and contribute to nature-based solutions for CO2 mitigation. Nonetheless, ongoing research and data updates are imperative to ensure that

conservation and management efforts are based on the latest insights into the region's seagrass ecosystems.

Chapter 3: Country Deep Dive – Deeper Assessment for Investment Opportunities in the Target Countries

This chapter enriches the results of the above regional assessment by providing a deeper assessment of the status and trends in the coastal ecosystems of the target countries, including Bangladesh, Indonesia, Maldives, and Samoa. Further information gathered through working with local/national organizations will help identify the implications of disruption of the flow of ecosystem services the resilience of local communities, key economic sectors, and key issues such as food security and disaster risk mitigation. Successful strategies developed in the selected countries based on co-benefits of climate action for mitigation and adaptation needs and showcase how natural climate solutions supporting that to be replicated in other Asia-Pacific countries with similar conditions.

This assessment examines the status of mangroves, coral reefs, and seagrass in the four target countries in the Asia-Pacific region to estimate the potential of nature-based solutions and pilot studies. The four countries represent a diverse range of coastal ecosystems (Table 12, Figure 18, Figure 19). Indonesia has a relatively good balance of ecosystems, with mangroves covering 44% of the total area covered by the three ecosystems in the coastal waters of the country, and the remaining 56% divided between coral reefs (30%) and seagrass (25%). Bangladesh's coastal waters, on the other hand, are dominated by mangroves, with coverage of around 84%. There is hardly any significant seagrass or coral reef habitat near the coastal area of Bangladesh (Table 12, Figure 18, Figure 19). Interestingly, the island countries of Maldives and Samoa support a dominant proportion of coral reefs and seagrass compared to small areas covered with mangroves (0.02% and 0.19%, respectively). Among these, Maldives has an equal proportion of seagrass (47.75%) and coral reefs (52%), while the coastal area of Samoa is dominated by seagrass (81% of the ecosystems) and has a relatively small proportion of coral reefs (19%). This implies that there is a huge potential for diverse nature-based solutions in these target countries in the region.

Table 12 Area cover and relative proportion of mangroves, coral reefs, and seagrass in the target countries. The relative proportion is calculated with respect to the total area covered by the three ecosystems in each country.
Source: Authors compilations from mangrove cover maps (Bunting et al., 2022), coral reef maps from Ocean Data Viewer (UNEP-WCMC, n.d.) which is based on several data sources including (IMaRS-USF, 2005; IMaRS-USF and IRD, 2005; Spalding et al., 2001; UNEP-WCMC et al., 2021)., and mapped area of seagrass (UNEP-WCMC and Short, 2021)

Target Country	**Mangrove**		**Coral Reef**		**Seagrass**	
	Area (ha)	Relative Proportion (%)	Area (ha)	Relative Proportion (%)	Area (ha)	Relative Proportion (%)
Indonesia	2,953,398	44.21	2042891	30.58	1684611	25.22
Bangladesh	448,386	84.07	4622	0.87	80323	15.06
Maldives	97	0.02	262184	52.23	239737	47.75
Samoa	232	0.19	22904	19.02	97289	80.79

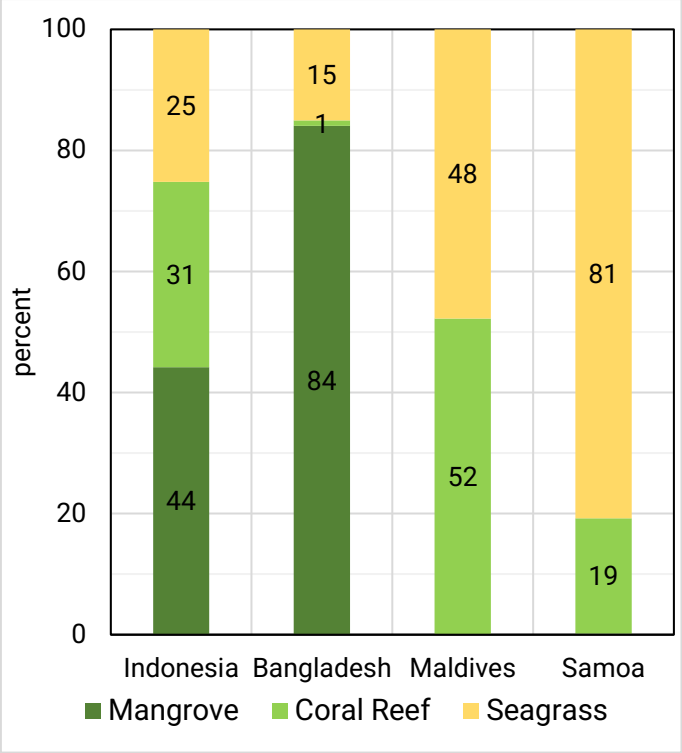

Figure 18 Relative proportion of mangrove, coral reef, and seagrass in the target countries
The relative proportion is calculated with respect to the total area covered by the three ecosystems in each country.
Source: Authors compilations from mangrove cover maps (Bunting et al., 2022), coral reef maps from Ocean Data Viewer (UNEP-WCMC, n.d.) which is based on several data sources including (IMaRS-USF, 2005; IMaRS-USF and IRD, 2005; Spalding et al., 2001; UNEP-WCMC et al., 2021)., and mapped area of seagrass (UNEP-WCMC and Short, 2021)

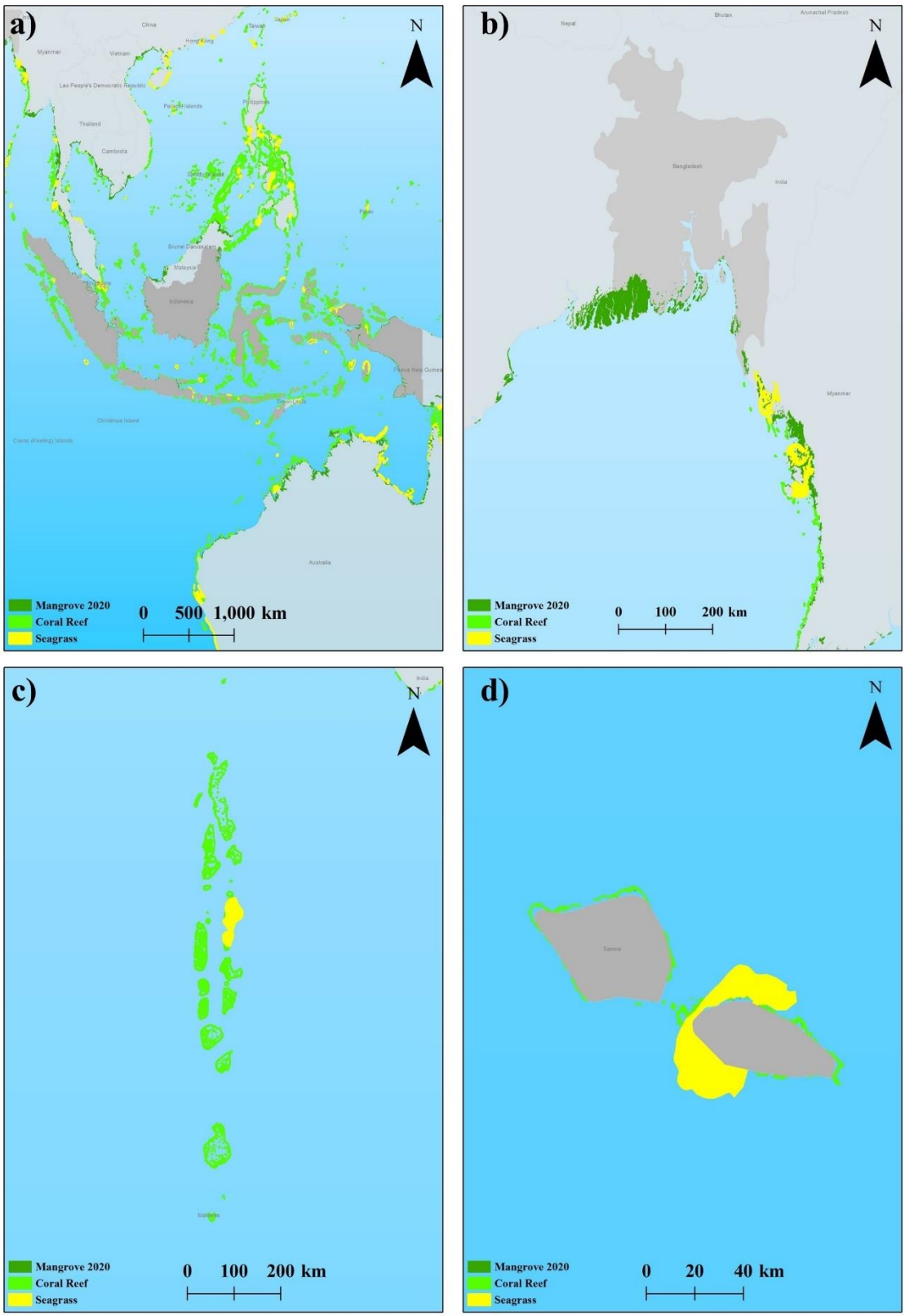

Figure 19 Spatial distribution of the coastal ecosystems (mangrove, coral reef, and seagrass) in the target countries – a) Indonesia, b) Bangladesh, c) Maldives, and d) Samoa.
Source: Authors compilations from mangrove cover maps (Bunting et al., 2022), coral reef maps from Ocean Data Viewer (UNEP-WCMC, n.d.) which is based on several data sources including (IMaRS-USF, 2005; IMaRS-USF and IRD, 2005; Spalding et al., 2001; UNEP-WCMC et al., 2021)., and mapped area of seagrass (UNEP-WCMC and Short, 2021)

Mangrove Extent in the Target Countries

Indonesia has lost 1,739.04 km² since 1996.

In 1996, the mangrove habitat area in **Indonesia** spanned 31,273.02 km². By 2010, it had decreased to 29,748.65 km², and in 2020, it further diminished to 29,533.98 km². The extent of mangroves in Indonesia witnessed a decline of 1,524.37 km² between 1996 and 2010, equivalent to an annual decrease of 101.62 km²per year. Over the period from 1996 to 2020, there was a reduction of 1,739.04 km², translating to an annual decrease of 69.56 km². In the most recent decade, from 2010 to 2020, mangroves diminished by 214.67 km², or 21.47 km² per year. While the overall reduction in mangrove loss has decreased, it's crucial to comprehensively assess the gains and losses in mangrove cover to mitigate losses and enhance gains. As mangroves are important carbon sinks that help to mitigate climate change, therefore, it is important to monitor and reduce losses due to deforestation (GMW, n.d.).

In contrast to the decline in mangrove cover in Indonesia, **Bangladesh** has experienced a gradual increase from 4,447 km² in 1996 to 4,484 km² in 2020. The extent of mangroves in Bangladesh observed a net gain of 36.68 km² between 1996 and 2020, resulting in an average annual increase of 1.46 km² (GMW, n.d.). Despite this assessment, the national-level evaluation in 2005-07 of Bangladesh, National Forest and Tree Resources Assessment 2005-2007, indicates a much higher mangrove cover of approximately 6000 km2, including 1900 km2 of afforestation of mangroves in the country.

Maldives, on the other hand, has maintained a consistent mangrove area of 97 ha since 1996, with no observable change in the extent of mangrove cover (GMW, n.d.). In the Maldives, there is a lack of comprehensive studies to determine national-level assessments of mangroves, as well as other key coastal ecosystems. Additionally, there have been undocumented efforts for mangrove restoration, and the actual area of mangrove cover might be greater than the estimates mentioned in the current study. There is a pressing need to establish a plan for conducting these assessments.

Similarly, **Samoa** has not seen significant fluctuations in its mangrove area. In 1996, the mangroves covered 234 ha, which increased to 239 ha in 2010 but then decreased to 232 ha in 2020. It is important to understand the drivers of these changes, the loss of 7 ha of mangroves over the last decade (GMW, n.d.).However, there is no significant studies have been conducted. FAO's assessment indicates a mangrove cover of 700 hectares in 1995 (Thuy and Thuy, 2019).

It's important to note that current global and regional assessments may not adequately capture the specific gains and losses at the national level, particularly in the case of island countries or territories.

National strategies for integrating blue carbon into Nationally Determined Contributions (NDCs) and climate policies exhibit diversity across the region. In Indonesia, a concerted effort is underway with the development of a Blue Carbon Strategy Framework. The objective is ambitious, aiming to restore 1.82 million hectares of mangrove ecosystems by the year 2045,

with an annual restoration target ranging from 60,000 to 90,000 hectares. Meanwhile, Samoa has taken proactive steps by initiating the Mangrove Ecosystems for Climate Change Adaptation and Livelihoods program, demonstrating a commitment to addressing climate challenges through mangrove conservation. In Bangladesh, the recognition of the crucial role played by mangroves in climate action is evident, even though the term 'blue carbon' is not explicitly used in its NDC. These distinct approaches highlight the varied yet essential efforts of nations in the region to incorporate blue carbon into their climate strategies.

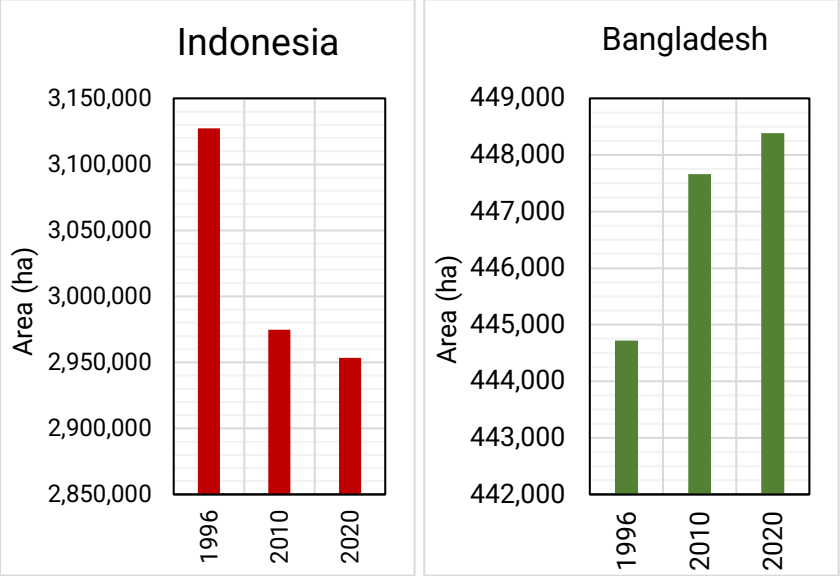

Figure 20 Mangrove covers extent in Indonesia and Bangladesh, 1996, 2010, and 2020.
Data Source: The data is extracted from (Bunting et al., 2022), Global Mangrove Watch Version 3.0 (GMW v3.0) (GMW, n.d.)

Table 13 Extent of mangroves in the target countries, 1996, 2010, and 2020 – Indonesia, Bangladesh, Maldives, and Samoa
Data Source: The data is extracted from (Bunting et al., 2022), *Global Mangrove Watch Version 3.0 (GMW v3.0) (GMW, n.d.)*

Country	**1996**	**2010**	**2020**	**Gain/Loss**		**Gain/Loss**		**Gain/Loss**	
				1996-2020		**2010-2020**		**1996-2010**	
	Area (ha)			Area (ha)	%	Area (ha)	%	Area (ha)	%
Indonesia	3,127,302	2,974,865	2,953,398	-173,903.84	-5.56	-21,466.44	-0.72	-152,437.39	-4.87
Bangladesh	444,717	447,661	448,386	3,668.63	0.82	725.04	0.16	2,943.59	0.66
Maldives	97	97	97	0.00	0.00	0.00	0.00	0.00	0.00
Samoa	234	239	232	-1.77	-0.76	-6.50	-2.72	4.73	2.02
Pakistan	100,002	89,579	82,789	-17,213.56	-17.21	-6,790.74	-7.58	-10,422.82	-10.42

Table 14 Net change in mangrove area since 1996 in the target countries
Data Source: The data is extracted from (Bunting et al., 2022), *Global Mangrove Watch Version 3.0 (GMW v3.0)*

	Indonesia	**Bangladesh**	**Maldives**	**Samoa**	**Pakistan**
Year	**Net Change (km2)**				
1996	0	0	0	0	0

2007	-957.78	42.36	0	0.03	-64.24
2008	-1,345.54	37.81	0	0.05	-84.03
2009	-1,442.98	31.07	0	0.06	-90.49
2010	-1,524.37	29.44	0	0.05	-104.23
2015	-1,707.66	14.89	0	0.03	-112.16
2016	-1,817.38	19.84	0	0.01	-99.42
2017	-1,864.79	10.75	0	-0.01	-80.05
2018	-1,861.95	33.05	0	-0.04	-72.37
2019	-1,838.86	27.33	0	-0.03	-99.96
2020	-1,739.04	36.69	0	-0.02	-172.14

Drivers of Mangrove Losses in the Target Countries

Major driver of mangrove loss is Oil-Palm and Aquaculture in Indonesia while erosion in Bangladesh.

In Indonesia, the primary cause of mangrove loss is attributed to the dominance of commodity production (agriculture and aquaculture), accounting for 75% of mangrove loss, mainly driven by oil palm plantations (

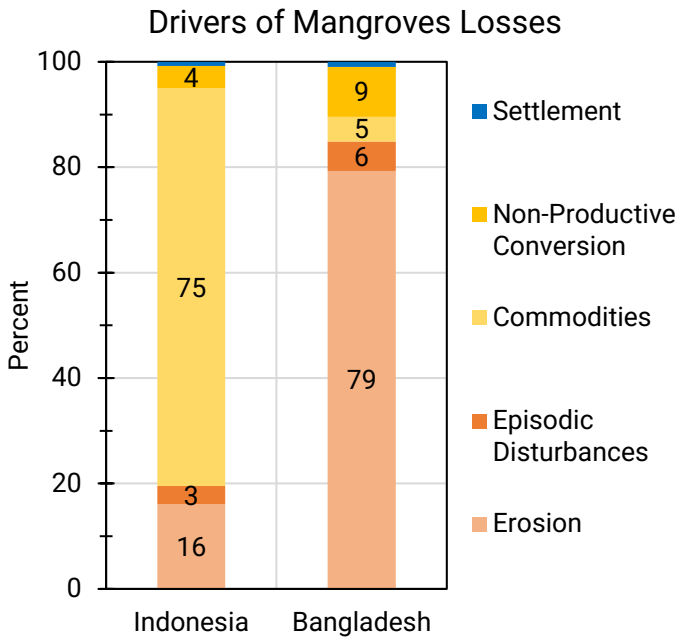

Figure 21). An additional 16% of loss is due to the natural process of erosion. On the other hand, since the mangroves in Bangladesh are well protected from the direct influence of anthropogenic drivers of change (

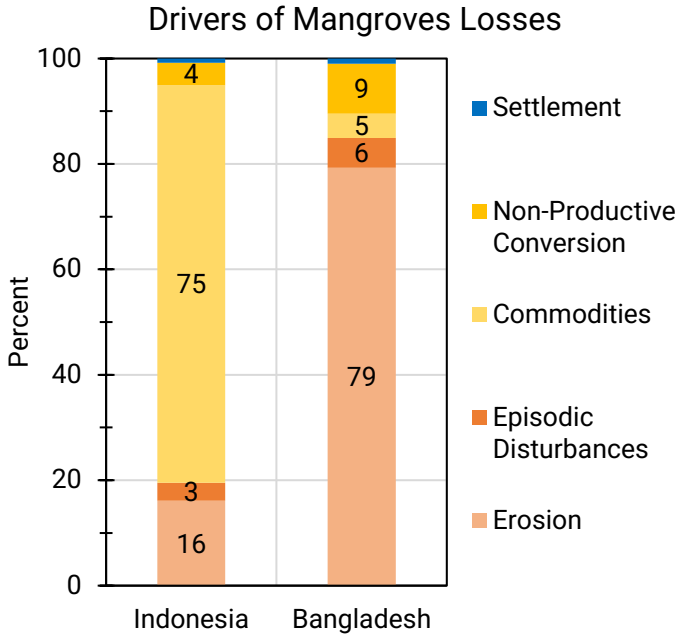

Figure 21), leading erosion (79%) being the major driver of mangrove loss, along with episodic disturbances (6 %) such as extreme climate events (Goldberg et al., 2020). In Oceania, another noteworthy factor leading to mangrove changes could be natural recreational activities(FAO, 2023).

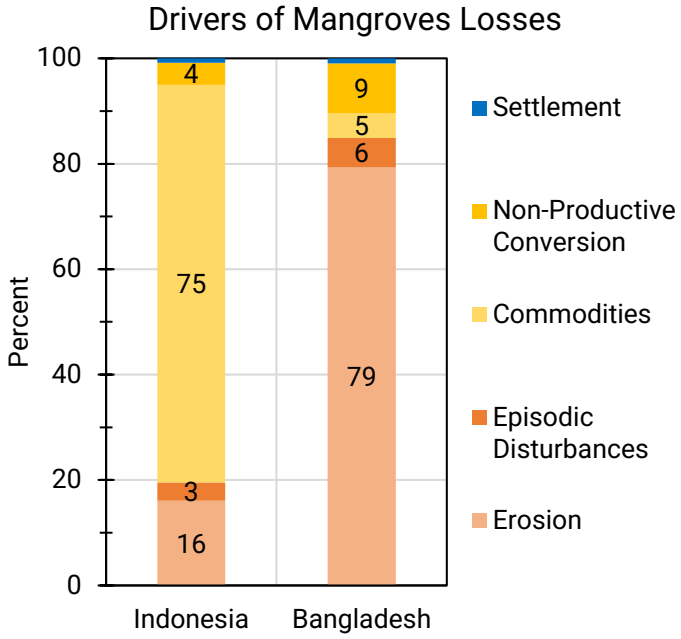

Figure 21 Major drivers of mangrove losses in Indonesia and Bangladesh
Source: Authors compilations from Global Mangroves Watch (GMW, n.d.)

Mangroves Species and IUCN Red List Status in the Target Countries

Indonesia exhibits a diverse range of mangroves with 47 different species, among these, 3 species are classified as threatened according to the IUCN Red List (Table 15). Similarly, Bangladesh displays a variety of 32 mangrove species, 2 of these species are considered threatened by the IUCN Red List. Maldives boasts 11 species of mangroves, and notably, all of these species fall under the "Least Concerned" category, signifying their healthy status. In Samoa, three distinct mangrove species are identified. Out of these, one is classified as threatened, while the remaining two are categorized as "Least Concerned" by the IUCN Red List (GMW, n.d.).

Table 15 Conservation status of mangrove species in the target countries
Source: Authors compilations from the Global Mangroves Watch (GMW, n.d.)

IUCN Red List	Indonesia	Bangladesh	Maldives	Samoa
Critically Endangered	2	1	0	0
Endangered	2	1	0	0
Vulnerable	1	0	0	0
Near Threatened	3	2	0	1
Least Concern	37	26	11	2
Data Deficient	2	2	0	0
Total Number of Species	47	32	11	3

Mangroves Protection Status in the Target Countries

Mangrove protection status varies significantly among the target countries, and to some extent this explains the losses and gains of mangroves in these countries (Table 14, Table 16).

In 2020, mangroves within protected areas accounted for 24.86% of the total mangrove area in **Indonesia**, totalling 7,343.20 km2 out of 29,533.98 km2 (GMW, n.d.).

Notably, **Bangladesh** had 88.5% of its mangroves protected, with 3,970.48 km2 within protected areas out of a total of 4,483.86 km2 (GMW, n.d.). This high level of protection likely contributes to the overall increase in mangrove cover.

Meanwhile, in the **Maldives**, only 23.63% of the total mangrove area was within protected areas in 2020, with 23.00 hectares out of 97.34 hectares being protected (GMW, n.d.).

Similarly, in **Samoa**, 19.3% of the mangroves were found in protected areas in 2020, accounting for 45.00 hectares out of a total of 232.18 hectares (GMW, n.d.).

Restoration Potential of Lost Mangroves Area in the Target Countries

A team of mangrove experts, representing institutions like the University of Cambridge, The Nature Conservancy, IUCN, the Global Mangrove Alliance, and others, utilized data from Global Mangrove Watch to create a map that traces the historical extent of mangroves from 1996 to 2020. They also pinpointed areas where mangroves have been lost and established a model to predict the factors conducive to restoration, enabling to identification of suitable

locations for mangrove restoration by recognizing areas where mangroves once flourished and where environmental conditions still support restoration efforts (Table 16) (Global Mangroves Watch - Worthington et al. (2023) (In Review) (GMW, n.d.).

Table 16 Restoration potential of the lost mangroves area
Source: Authors compilations from Global Mangroves Watch, Worthington et al. (2023) (In Review). (GMW, n.d.)

	Indonesia		Bangladesh		Maldives		Samoa	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Mangrove area in 2020	2,953,398		448,386		97		232	
Mangroves in Protected Area	734320	24.86	397048	88.5	23	23.63	45	19.3
Total Mangrove Area Loss	253,641		28,516				22	
Mangroves Restoration Potential Score	79		75				82	
Non-restorable lost mangrove area	49,105.40	19.36	22,590.65	79.22			5.67	25.71
Restorable Lost Mangrove Area	204,536.17	80.64	5,925.65	20.78			16.39	74.33

In **Indonesia**, the cumulative mangrove area that has been lost amounts to 253,641 hectares. Among this loss, 49,105 hectares, equivalent to 19%, are categorized as non-restorable. Meanwhile, the remaining 204,536 hectares, accounting for 81% of the total mangrove area loss, are considered restorable. These restorable mangrove areas make up 6.92% of the entire mangrove area, in 2020.

In **Bangladesh**, the total mangrove area lost has reached 28,516 hectares. Out of this loss, a significant portion, specifically 22,590 hectares or 79%, is classified as non-restorable. The remaining 5,925 hectares, constituting 21% of the overall mangrove area loss, are categorized as restorable. These restorable mangrove areas make up 1.32 % of the country's entire mangrove area in 2020.

In **Samoa**, the cumulative mangrove area that has been lost amounts to 22 hectares. Among this loss, 5.67 hectares, equivalent to 25%, are categorized as non-restorable. Meanwhile, the remaining 16.39 hectares, accounting for 75% of the total mangrove area loss, are considered restorable. These restorable mangrove areas make up 7% of the entire mangrove area, in 2020.

Increase in the Value of Ecosystem Services from the Restoration

The restoration of the potentially restorable area will provide ecosystem services with a net worth of 39,647.9 million US$ in **Indonesia**, 1,148.6 million US$ in Bangladesh, and 3.2 million US$ in Samoa (Table 17).

The restoration of mangroves also offers a nature-based solution by effectively capturing a substantial amount of CO2. Specifically, the above-ground biomass resulting from this restoration effort has the potential to store 38.5 Mt CO2 in **Indonesia**, 0.88 Mt CO2 in **Bangladesh**, and 0.003 Mt CO2 in **Samoa**.

When considering the additional benefit of restoring organic soil carbon, the figures rise to 114.76 Mt CO2 in Indonesia, 1.2 Mt CO2 in Bangladesh, and 0.006 Mt CO2 in Samoa.

Altogether, the total carbon sequestration amounts to 153.30 Mt CO2 equivalent in Indonesia, 2.09 Mt CO2 equivalent in Bangladesh, and 0.01 Mt CO2 equivalent in Samoa.

Table 17 Ecosystem services provided by the restorable mangroves area
Source: Authors compilations from Global Mangroves Watch, Worthington et al. (2023) (In Review). (GMW, n.d.

Service Category	Indonesia	Bangladesh	Maldives	Samoa
Ecosystem Service Value (million US$) (@US$193,843 per ha per year)	39,647.9	1,148.6		3.2
Nature-based Solution Carbon Sequestration				
Aboveground Carbon Mt CO2	38.54	0.88		0.003
Soil Organic Carbon Mt CO2	114.76	1.21		0.006
	153.30	2.09		0.01
Enhanced the Production of New Individuals for Commercial Purposes				
Fish	8,033,451,767	2,432,854		301,542
Crab	41,806,518	12,058		1,588
Shrimp	13,212,010,597	2,864,392		

Coral Reef Extent in the Target Countries

Coral reefs are a vital part of Indonesia's coastal regions, spanning approximately 2.04 million hectares, making it the largest expanse among the target countries. Intriguingly, substantial coral reef areas can also be found in the coastal regions of the Maldives, covering 262,184 hectares, as well as Samoa, where they span 22,904 hectares (Figure 19, Figure 18, Table 12). The relatively compact landmasses of the Maldives and Samoa accentuate the ecological importance of their extensive coral reef systems. These regions are deserving of dedicated efforts to ensure their preservation, as these ecosystems play a pivotal role not only in the nations' environmental health but also in maintaining the global ecological equilibrium. In contrast, Bangladesh's coastal areas are notably lacking in well-documented coral reef habitats, highlighting the need for further exploration and conservation efforts in this region. Indonesia's extensive coral reef coverage underscores the importance of preserving and protecting these ecosystems, not only for the country but for the entire marine environment of the Asia Pacific. Efforts to study and conserve coral reefs in the Maldives and Samoa should also continue, and special attention should be given to Bangladesh to better understand and safeguard any potential coral reef habitats in that region.

It's worth mentioning that, in terms of relative proportions among the three coastal ecosystems (mangroves, seagrass, and coral reefs), Indonesia and Samoa exhibit the second highest proportion of coral reefs. Meanwhile, in the Maldives, coral reefs dominate the coastal ecosystem with the highest coverage.

Threats to Coral Reef and Conservation Priority Areas in the Target County

Indonesia, as one of the largest habitats for coral reefs, presents a pessimistic scenario where three-fourths of the coral reefs are expected to fall into the critical (8%), very high (20%), and high (44%) threat categories by 2030, with a worsening outlook by 2050 (Figure 22, Figure 23, Table 18). These threats stem from a combination of local and global factors, including human pressures on coral reefs. Local threats addressed in this analysis encompass coastal development, watershed-based pollution, marine-based pollution, damage, overfishing, and destructive fishing. Global threats include thermal stress, driven by warming sea temperatures leading to coral bleaching, and ocean acidification, driven by increased CO2 levels resulting in reduced coral growth rates (Burke et al., 2011).

Maldives, in the current scenario, predominantly harbors coral reefs within a medium to low-risk category, and these reefs remain relatively stable in the projected outlook for 2030 (Figure 22, Figure 23, Table 18). This stability can be attributed primarily to the limited direct human influence on the quality of ocean water. However, under the 2050 projection, approximately 35% of the coral reefs in Maldives will face high (24%) and very high (11%) threats.

In stark contrast, the coral reefs around **Samoa** are anticipated to be highly threatened by 2030 (Figure 22, Figure 23, Table 18). Most of the coral reefs along the northwestern coasts of

Samoa will be critically threatened, while the coral in the southern and southeastern coasts will be under very high threat by 2030.

In the context of coral reefs, it is noteworthy that there are minimal documented instances of coral reefs within the ocean waters of **Bangladesh**. As a result, there are no identified threats within this target country. The primary area of concern pertains to mangroves, which may be affected by the quality of ocean water in the intertidal zones.

The provided table (Table 18) illustrates the distribution of threatened reef categories in the target countries. The proposed areas for conservation priorities should focus on averting losses in ecosystem services and mitigating direct or indirect carbon losses stemming from the degradation of coral reefs.

The spatial distribution of at-risk coral reefs in the coastal areas of the target countries, both in the present and projected threats for 2050, is delineated in the Annex (Annex IV: Maps of Distribution of Coral Reefs at Risk in the Asia Pacific).

Investment to rescue projected threatened coral reefs are by 2030 in Indonesia could worth an ecosystem service value of 900 million $US yearly in Indonesia, while 41.53 million $US per year in Maldives and 11. 86 million $US per year in Samoa (Table 18).

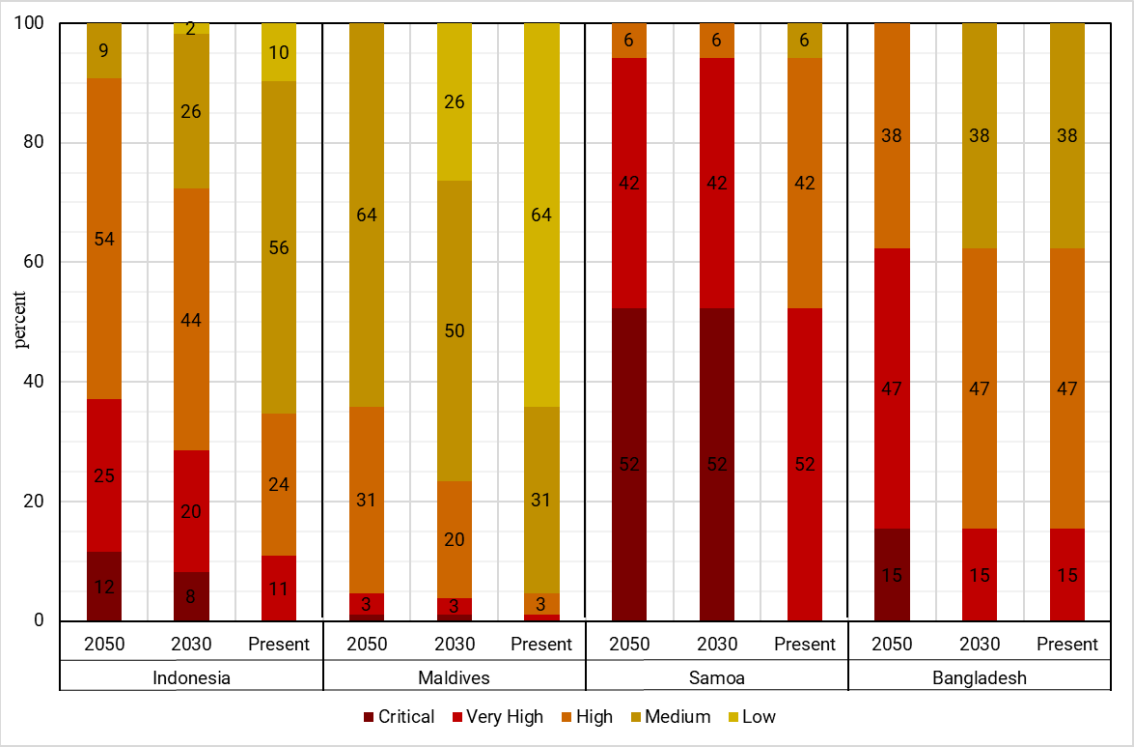

Figure 22 Categorization of the coral reefs at risk (present, projected 2030, and 2050) from the integrated local and global threats in the Asia Pacific region for the target countries including Indonesia, Bangladesh, Maldives, and Samoa (Burke et al., 2011).
The coastal waters of Bangladesh do not have significant recorded coral reef sites, therefore its stats could be ignored for Coral Reef.
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included

Coastal development, Watershed-based pollution, Marine-based pollution, and damage, Overfishing and destructive fishing. Global threats covered Thermal stress (warming sea temperatures, which can induce coral bleaching) and Ocean acidification (driven by increased CO2, which can reduce coral growth rates) (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

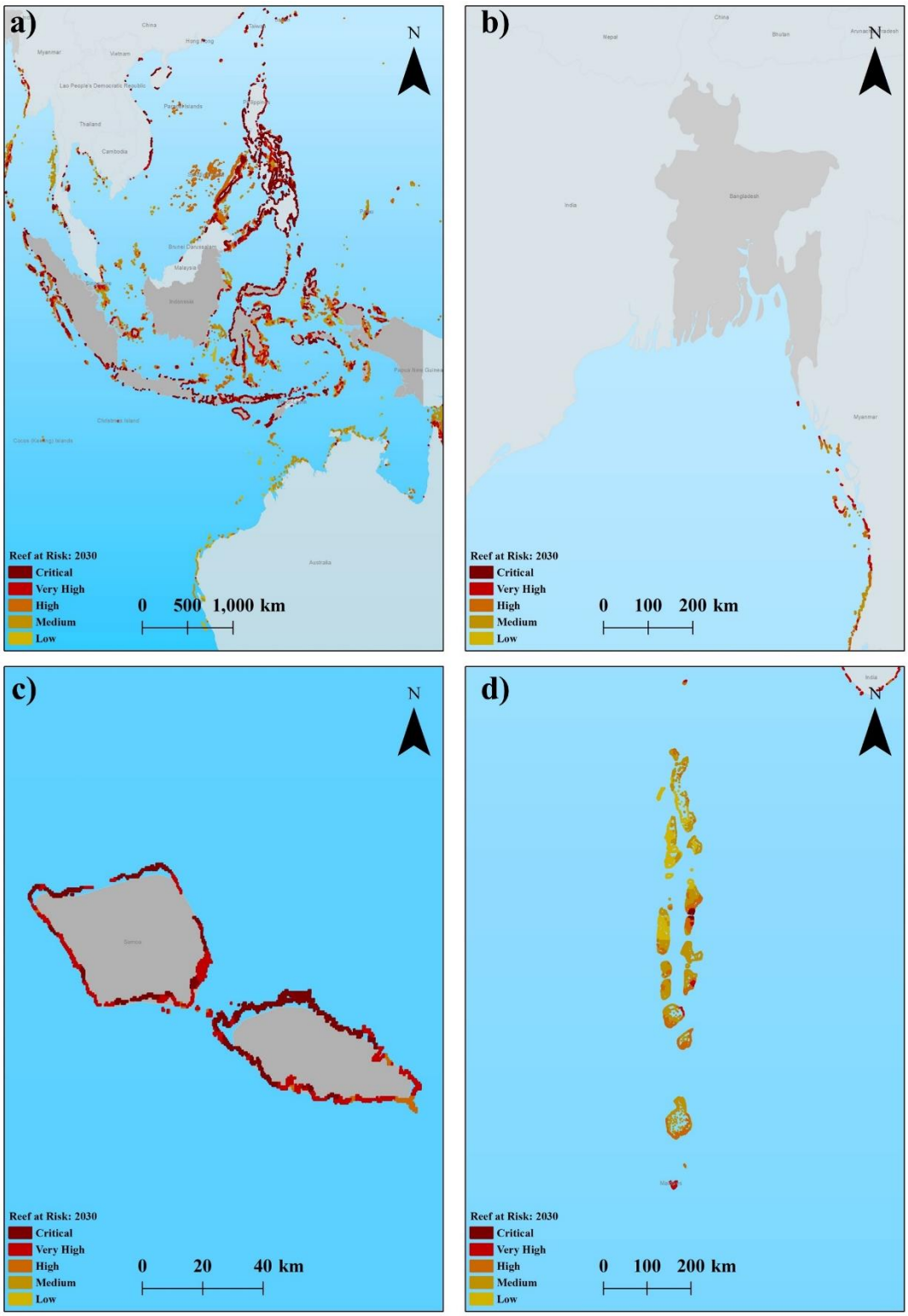

Figure 23 Distribution of categories of projected coral reefs at risk by 2030 in the target countries – a) Indonesia, b) Bangladesh, c) Maldives, and d) Samoa

The data is extracted from the integrated local and global threats projected from 2030 in the Asia Pacific region (Burke et al., 2011). The analysis was based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, and damage, Overfishing and destructive fishing. Global threats covered Thermal stress (warming sea temperatures, which can induce coral bleaching) and Ocean acidification (driven by increased CO2, which can reduce coral growth rates) (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

Table 18 Coral Reefs for conservation and restoration priorities in the target countries (Indonesia, Bangladesh, Maldives, and Samoa) based on the assessment of coral reefs at risk (present, projected for 2030, and 2050) due to combined impacts of local and global threats. (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

	Category	Indonesia			Maldives			Samoa			Bangladesh		
		2050	2030	Present	2050	2030	Present	2050	2030	Present	2050	2030	Present
Area in hectare													
Target Areas for Conservation Priority and Restoration	**Critical**	401943	286951		5619	5619		17626	17626		1500		
	Very High	885407	703326	378445	17248	13577	5619	14105	14105	17626	4550	1500	1500
	High	1864152	1520716	827509	157203	98193	17248	1944	1944	14105	3650	4550	4550
Target Area for Long-Term Conservation Plans	**Medium**	322383	902788	1932085	322496	252525	157203			1944		3650	3650
	Low		60104	335847		132652	322496						
Area (%)													
Target Areas for Conservation Priority and Restoration	**Critical**	12	8	0	1	1	0	52	52	0	15	0	0
	Very High	25	20	11	3	3	1	42	42	52	47	15	15
	High	54	44	24	31	20	3	6	6	42	38	47	47
Target Area for Long-Term Conservation Plans	**Medium**	9	26	56	64	50	31	0	0	6	0	38	38
	Low	0	2	10	0	26	64	0	0	0	0	0	0
Ecosystem Service Value Investment Ecosystem Services (million $US) @352249 per hectare (Costanza et al., 2014)													
Target Areas for Conservation Priority and Restoration	**Critical**	141.58	101.08	0.00	1.98	1.98	0.00	6.21	6.21	0.00	0.53	0.00	0.00
	Very High	311.88	247.75	133.31	6.08	4.78	1.98	4.97	4.97	6.21	1.60	0.53	0.53
	High	656.65	535.67	291.49	55.37	34.59	6.08	0.68	0.68	4.97	1.29	1.60	1.60
Target Area for Long-Term Conservation Plans	**Medium**	113.56	318.01	680.58	113.60	88.95	55.37	0.00	0.00	0.68	0.00	1.29	1.29
	Low	0.00	21.17	118.30	0.00	46.73	113.60	0.00	0.00	0.00	0.00	0.00	0.00

Seagrass Extent in the Target Countries

In the coastal waters of **Indonesia**, the seagrass area spans 1.68 million hectares, making it the largest in terms of sheer coverage (Figure 18, Figure 19, Table 12). However, when considering the proportion of seagrass relative to the total area of coastal ecosystems, including mangroves and coral reefs, seagrass makes up only 25% (UNEP-WCMC and Short, 2021). Another study has reported seagrass area of Indonesia is around 3 million ha with a carbon storage potential of 119.5 Mg C per ha (Thuy and Thuy, 2019), compared to an average of 140 Mg Corg per ha (Pendleton et al., 2012; Serrano et al., 2021).

In the **Maldives**, seagrass extends across 239,737 hectares, sharing a proportion like coral reefs. In **Samoa**, the seagrass area is 97,289 hectares, surpassing the relative proportions of the other coastal ecosystems, such as mangroves and coral reefs (Figure 22, Figure 23, Table 18).

Conversely, **Bangladesh** exhibits the least amount of seagrass coverage and the lowest proportion compared to the other coastal ecosystems (Figure 18, Table 12). In Bangladesh's oceanic waters, seagrass presence is nearly non-existent, which suggests the need for further exploration and study in this area. These relative proportions shed light on the composition of coastal ecosystems across these regions. Indonesia stands out for its well-balanced mix of the three ecosystems, including seagrass, mangroves, and coral reefs. Bangladesh, on the other hand, is dominated by mangroves, while Samoa's waters are primarily characterized by an abundance of seagrass. The Maldives, interestingly, boasts an almost equal distribution of seagrass and coral reefs but contains the fewest mangroves (UNEP-WCMC and Short, 2021).

According to the UNEP-WCMC database (UNEP-WCMC and Short, 2021), there are four sights recorded in Samoa, three in Maldives, four in Bangladesh, and 380 in Indonesia.

A recent study (Sudo et al., 2021) demonstrated that there are 861 documented sightings of seagrass beds within **Indonesia's coastal waters**, which is greater than the current total by the UNEP-WCMC seagrass (UNEP-WCMC and Short, 2021). Of these sightings, 228 provide coordinates pinpointing the locations of these vital seagrass habitats, while 633 utilize polygons to delineate the areas these seagrass beds occupy (Sudo et al., 2021). This requires further investigation for all the target countries to document all the seagrass sightings, marked areas, temporal changes in the extent and health of the habitat as well as biomass potential.

Threats to Seagrass and Conservation Priorities in the Target Countries

An overlay analysis of the seagrass sighting locations with the Combined Human Impact (CHI) (Halpern et al., 2019, 2008a, 2008b) to the marine ecosystems shows the exposure of seagrass ecosystem to the direct and indirect human impacts. The results are categorised into five classes of risk including Critical (>4), Very High (3-4), High (2-3), Medium (1-2), and Low (<1) (Figure 24, Figure 25, Table 19, Table 20). Details on the analysis are given in the section - Conservation and Restoration of Seagrasses.

Reduction of potential losses and degradation from seagrass can provide a nature-based solution by fixing around 224 Mt CO2 in Indonesia, 40 Mt CO2 in Maldives and 3.6 Mt CO2 in Samoa (Table 19).

Considering the small sample size of Maldives and Samoa, the global assessments might not be relevant at the local scale threats and risks to the seagrass habitat. For instance, the land subsidence will exacerbate the impact of sea level rise, particularly in the Pacific islands. Sea level rise is already impacting coastal communities in the Asia Pacific region, causing flooding, erosion, and saltwater intrusion. Sea level rise in the Asia Pacific region could exceed two meters by 2100. This high rate of sea level rise comes from the combined effects of land subsidence and climate change. Most islands in the Pacific are subsiding due to the extraction of groundwater (Gravelle et al., 2023), therefore the effect of sea-level rise will be magnified where the land is falling. In addition, the low adaptative capacity of the Pacific Island countries to climate change poses a serious risk to coastal ecosystem services and infrastructures (ADB, 2022).

Nevertheless, it is crucial to emphasize the lack of existing literature and assessments concerning the ever-changing nature of these seagrass beds in the coastal regions of Indonesia and other targeted countries. This knowledge deficit underscores a significant gap in our understanding of nature-based solutions and the untapped potential for investments related to the pivotal role that seagrass beds play in the intricate dynamics of carbon sequestration and release within the region. Addressing these gaps is imperative for harnessing the full ecological and climate-regulating potential of these invaluable seagrass ecosystems.

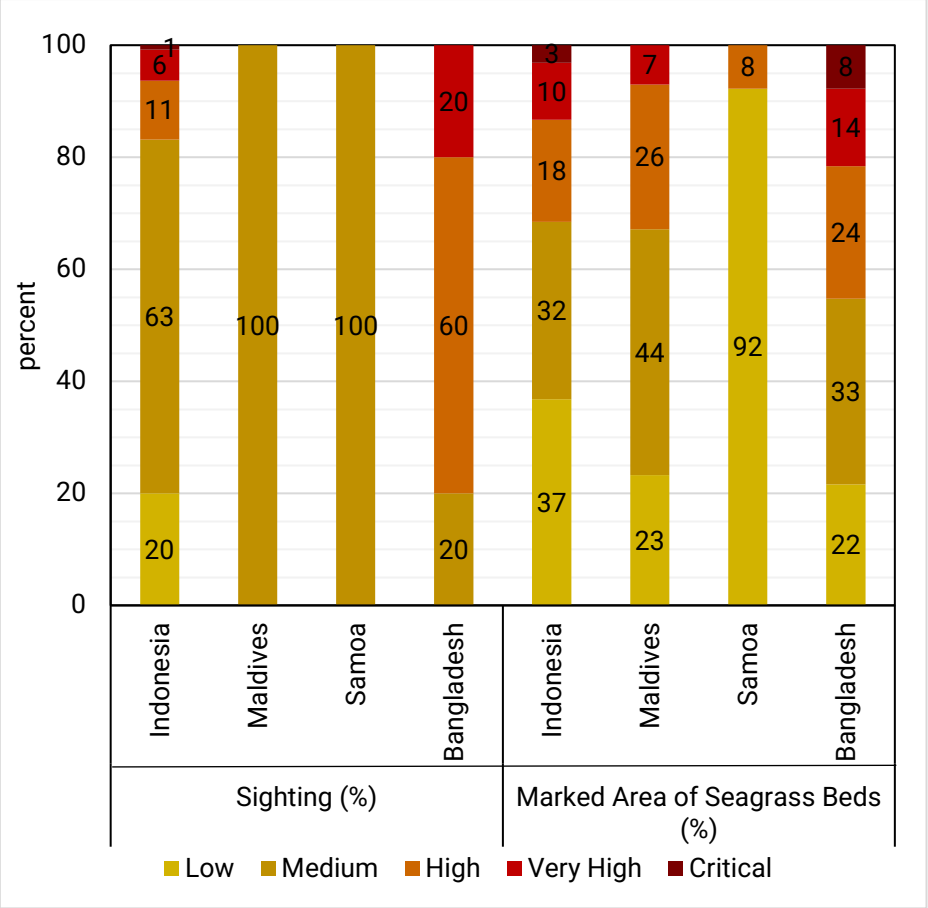

Figure 24 Categorization of the Combined Human Impact (Halpern et al., 2019, 2008a, 2008b) on the Seagrass (UNEP-WCMC and Short, 2021) in the Asia Pacific region for the target countries including Indonesia, Bangladesh, Maldives, and Samoa.
Source: Authors compilation from (Halpern et al., 2019, 2008a, 2008b) and (UNEP-WCMC and Short, 2021)
Note: Considering the small sample size of Maldives and Samoa, the global assessments might not be relevant at the local scale threats and risks to the seagrass habitat. These statistics could be revised provided localized data is available.
An overlay analysis of the seagrass sighting locations with the Combined Human Impact (CHI) on the marine ecosystems shows the exposure of the seagrass ecosystem to direct and indirect human impacts.

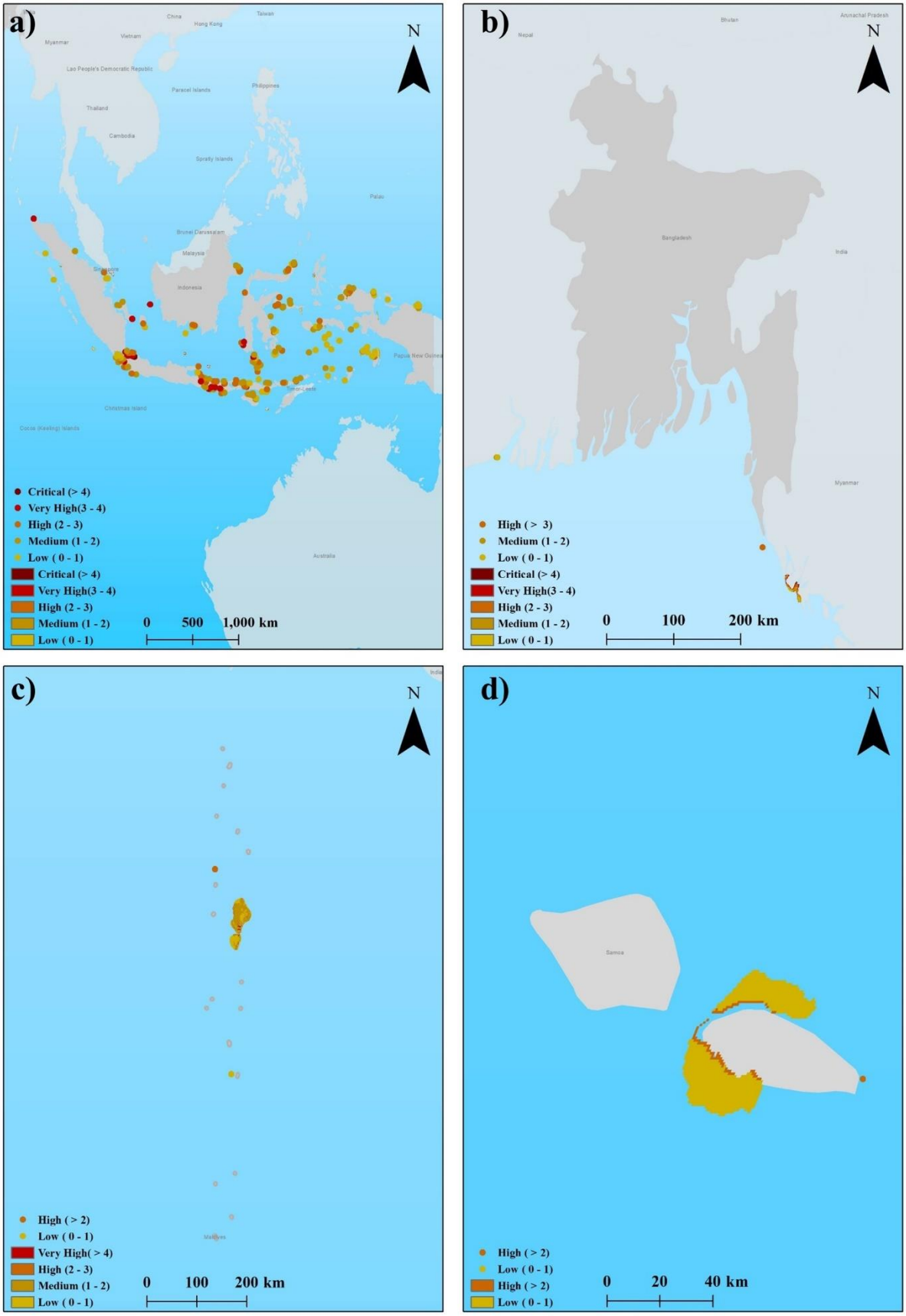

Figure 25 Spatial distribution of Combined Human Impact (Halpern et al., 2019, 2008a, 2008b) on the Seagrass (UNEP-WCMC and Short, 2021) in the Asia Pacific region for the target countries including Indonesia, Bangladesh, Maldives, and Samoa.

Source: Authors compilation from (Halpern et al., 2019, 2008a, 2008b) and (UNEP-WCMC and Short, 2021)
Note: Considering the small sample size of Maldives and Samoa, the global assessments might not be relevant at the local scale threats and risks to the seagrass habitat. These statistics could be revised provided localized data is available.
An overlay analysis of the seagrass sighting locations with the Combined Human Impact (CHI) on the marine ecosystems shows the exposure of the seagrass ecosystem to direct and indirect human impacts.

Table 19 Marked area of seagrass for conservation and restoration priorities in the target countries (Indonesia, Bangladesh, Maldives, and Samoa) based on the categorization of the Combined Human Impact (Halpern et al., 2019, 2008a, 2008b) on the Seagrass (UNEP-WCMC and Short, 2021) in the Asia Pacific.
Source: Authors compilation from (Halpern et al., 2019, 2008a, 2008b) and (UNEP-WCMC and Short, 2021)
Note: Considering the small sample size of Maldives and Samoa, the global assessments might not be relevant at the local scale threats and risks to the seagrass habitat. These statistics could be revised provided localized data is available.

Category	Marked Area of Seagrass Beds (ha)			
	Indonesia	**Maldives**	**Samoa**	**Bangladesh**
Area (ha)				
Low	508843	55189	84269	5589
Medium	438197	104266		8558
High	252195	61302	7073	6113
Very High	140855	16679		3580
Critical	43575			2008
Area (%)				
Low	37	23	92	22
Medium	32	44	0	33
High	18	26	8	24
Very High	10	7	0	14
Critical	3	0	0	8
Ecosystem Service Value Investment				
Ecosystem Services (billion $US) @352249 per hectare (Costanza et al., 2014)				
Low	14.71	1.60	2.44	0.16
Medium	12.67	3.01	0.00	0.25
High	7.29	1.77	0.20	0.18
Very High	4.07	0.48	0.00	0.10
Critical	1.26	0.00	0.00	0.06
Carbon Fixation				
Carbon (megatons) @ 140 Mg Corg per ha (Pendleton et al., 2012; Serrano et al., 2021)				
Low	71.24	7.73	11.80	0.78
Medium	61.35	14.60	0.00	1.20
High	35.31	8.58	0.99	0.86
Very High	19.72	2.34	0.00	0.50
Critical	6.10	0.00	0.00	0.28
CO2 (megatons) @ 513.8 MgCO2 per ha (Pendleton et al., 2012; Serrano et al., 2021)				
Low	261.44	28.36	43.30	2.87
Medium	225.15	53.57	0.00	4.40
High	129.58	31.50	3.63	3.14
Very High	72.37	8.57	0.00	1.84
Critical	22.39	0.00	0.00	1.03

Table 20 Sighted location of seagrass habitats for conservation and restoration priorities in the target countries (Indonesia, Bangladesh, Maldives, and Samoa) based on the categorization of the Combined Human Impact (Halpern et al., 2019, 2008a, 2008b) on the Seagrass (UNEP-WCMC and Short, 2021) in the Asia Pacific.
Source: Authors compilation from (Halpern et al., 2019, 2008a, 2008b) and (UNEP-WCMC and Short, 2021)
Note: Considering the small sample size of Maldives and Samoa, the global assessments might not be relevant at the local scale threats and risks to the seagrass habitat. These statistics could be revised provided localized data is available.

Category	Sighting			
	Indonesia	Maldives	Samoa	Bangladesh
Low	76			
Medium	240	3	4	1
High	40			3
Very High	21			1
Critical	3			
	380	3	4	5

Chapter 4: Conclusions and Recommendations

This assessment underscores the profound importance of blue carbon ecosystems in the Asia-Pacific region as vital components of nature-based solutions to combat the adverse effects of climate change. This region harbors approximately 50% of the world's mangroves, a quarter of the global seagrass, and over three-quarters of the world's coral reefs, all of which have a profound influence on climate regulation, socio-economic well-being, and the livelihoods of coastal communities, particularly those residing in low-lying areas.

Regrettably, these exceptionally diverse and globally significant resources in the region are under threat, with rapid depletion attributed to both direct human impacts on a local scale and indirect human influences such as climate change on a global or regional scale. A substantial portion of these ecosystem resources has already been lost or degraded, while an additional 30-50% remain vulnerable to changing environmental conditions and direct human pressures.

Fortunately, there is a unique opportunity for the restoration, conservation, and protection of ecosystem services valued at four to five trillion US dollars and the mitigation of CO2 emissions, ranging from 650 million to 5 gigatons, by 2030. Nevertheless, knowledge about these ecosystems varies across different stages of development. Mangroves, for instance, have advanced in terms of mapping and require models that offer spatially exclusive data for carbon sequestration, precise area estimation, and the potential for habitat restoration. In contrast, seagrass ecosystems are still in their early stages of mapping and monitoring, lacking comprehensive data regarding their extent, temporal changes, and degradation. Extensive research is imperative for the development of methods in this regard, especially for seagrass ecosystems, which are pivotal carbon sequestration hubs, requiring significant investments and focused monitoring and modeling efforts.

This scenario presents a remarkable investment opportunity, not only to safeguard and conserve these ecosystems to prevent the release of stored carbon into the atmosphere but also to restore and enhance their habitats through resource cooperation and ecosystem-based adaptation, benefiting the millions of people who reside in low-lying coastal areas and rely on fisheries in the Asia-Pacific region.

Moreover, this assessment underscores the importance of developing comprehensive monitoring, mapping, and modeling methodologies for national and local assessments in various cycles across four different countries. These methodologies are critical for understanding the driving forces and dynamics of these ecosystems and for creating models that can inform regional-scale assessments. Over time, this iterative process may lead to the creation of carbon credit investments in the region.

Furthermore, this assessment unveils the potential of blue carbon as a nature-based solution and pilot programs in countries such as Indonesia, Bangladesh, Maldives, and Samoa. It showcases how the restoration of mangroves can effectively sequester substantial carbon, provide invaluable ecosystem services, and yield substantial returns on investments. Additionally, investments in the restoration and preservation of mangroves, coral reefs, and the addressing of seagrass degradation can significantly contribute to carbon sequestration and

climate adaptation efforts. However, it is crucial to acknowledge the existing knowledge gap regarding these blue carbon ecosystems in the region, emphasizing the need for further research to unlock their full potential in ecological and climate-regulating terms.

In summary, the Asia-Pacific region has a substantial demand for nature-based solutions, contributing more than 30% of all global nature-based credits, amounting to 85 million tonnes. Nonetheless, investments in nature-based solutions have primarily concentrated on terrestrial ecosystems like forests, leaving the critical coastal ecosystems of mangroves, seagrass, and coral reefs somewhat overlooked. Integrating blue carbon into the Nationally Determined Contributions (NDCs) of the region's countries presents a series of challenges that require immediate attention.

Annexes

Annex I. Drivers of Mangroves Losses in the Asia Pacific

Threats from Seal level rise to mangroves

The most significant threat to mangroves is projected to come from rising sea levels due to global warming. This threat has far-reaching implications for the valuable contributions of mangroves to the well-being of people, particularly in countries like Bangladesh, the Philippines, New Zealand, Viet Nam, and China (IPBES, 2018).

The projected increase in Global Means Sea Level (GMSL) asserts an increase in the frequency of currently rare Extreme Sea Level (ESL) events by the end of the 21st century, affecting low-lying cities and small islands with such events (IPCC, 2022a). The annual rate of GMSL has increased from 1.4 mm during 1901 – 1990 to 3.2 mm during 1993 – 2015 to 3.6 mm during 2006 – 2015 (IPCC, 2022a). The future rise in global mean sea level (GMSL) is strongly dependent on the amount of greenhouse gases emitted into the atmosphere. The higher the emissions, the higher the sea level rise. Under the most optimistic emissions scenario (RCP2.6), GMSL is projected to rise by half a meter (0.43 m) by 2100 which could be doubled under the most pessimistic emissions scenario (RCP8.5). This rise in sea level will have significant impacts on coastal communities around the world. Sea level rise is not globally uniform, and it varies regionally, relative to 1986 – 2005 (IPCC, 2022a).

The expectation of future coastal flooding is due to the global sea level increase of 3.2 mm/year in recent decades (Church and White, 2011) and the projected rise of sea levels by 0.28 to 0.98 meters by 2100 (IPCC, 2013). Additionally, regional factors play a substantial role in influencing these dynamics (Ward et al., 2016).

The **rising sea levels** pose a particular threat to mangroves in countries like Bangladesh, New Zealand, Viet Nam, and China. As sea levels rise, mangrove areas are likely to decline initially and, if land is available, migrate inland. Some studies also suggest that rising temperatures may lead to a poleward migration of mangroves, potentially bringing about changes in species composition, as exemplified by the findings of Gilman et al. (2008) (Gilman et al., 2008).

The rising sea levels pose a significant climate change threat to mangrove ecosystems due to their sensitivity to changes in inundation frequency, duration, and salinity levels that surpass their species-specific physiological tolerance thresholds (as noted in (Friess et al., 2012)). Prolonged periods of flooding can result in the death of plants at the outermost edges of mangrove areas (as observed in (Friess et al., 2012)) and trigger shifts in species composition (as indicated by (Gilman et al., 2008)). These changes ultimately lead to a decrease in productivity and the services provided by the ecosystem (Ward et al., 2016).

Mangrove sediment surface elevations, in most cases, are not keeping pace with rising sea levels, although more comprehensive, long-term studies from a wider range of regions are required to fully understand this phenomenon. The impact of rising sea levels will be most

pronounced in mangrove areas where the sediment elevation is decreasing and there is limited space for landward migration (Gilman et al., 2008).

Pacific Islands' mangroves are highly vulnerable to significant reductions.

Pacific Islands' mangroves are highly vulnerable to significant reductions. While there is less certainty about other potential climate change outcomes and mangrove responses, there is a pressing need for further research to develop assessment methods and standard indicators that can gauge these responses to climate change effects. Regional monitoring networks should also be established to systematically observe these responses and inform informed adaptation strategies (Gilman et al., 2008).

Land subsidence will exacerbate the impact of sea level rise, particularly in the Pacific islands.

Sea level rise is already impacting coastal communities in the Asia Pacific region, causing flooding, erosion, and saltwater intrusion. Sea level rise in the Asia Pacific region could exceed two meters by 2100. This high rate of sea level rise comes from the combined effects of land subsidence and climate change. Most islands in the Pacific are subsiding due to the extraction of groundwater (Gravelle et al., 2023), therefore the effect of sea-level rise will be magnified where the land is falling. In addition, the low adaptative capacity of the Pacific Island countries to climate change poses a serious risk to coastal ecosystem services and infrastructures (ADB, 2022).

Precipitation can increase sediment input while the temperature can impact mangroves to assimilate CO2.

Changing rainfall patterns are likely to affect the distribution, extent, and growth rates of mangrove forests, especially those at the edge of their tolerances. Extreme changes in precipitation can alter seasonal average salinity in some mangrove systems. Decreases in precipitation and increases in evaporation can lead to increases in soil salinity, which can decrease seedling survival, productivity, and growth rates. This can lead to mangrove loss and conversion to hypersaline mudflats over decadal timeframes. On the other hand, an increase in precipitation is likely to increase river discharge, which can lead to increased sediment inputs to estuarine mangroves. This can help to raise the surface elevation of mangroves, making them more resilient to sea level rise. In addition, the response of mangroves to changes in precipitation could be species-specific and vary with regional or localized settings (Duke et al., 1998; Eslami-Andargoli et al., 2009; Gilman et al., 2008; Ward et al., 2016).

Increasing temperatures are likely to affect the composition, timing of life cycles, productivity, and distribution of mangrove species. It can influence the ability of mangroves to assimilate carbon dioxide (CO2). Currently, many mangroves are confined to areas where the coldest monthly air temperature is at least 16°C. Mangroves also have peak leaf photosynthesis at 28–32°C (Duke et al., 1998), and low sea temperatures can limit the floating time of propagules

(Duke et al., 1998). In response to changes in temperature, mangroves can expand into salt marsh communities, however, the landward expansion of mangroves could be limited by the loss of habitat due to human-induced land use changes.

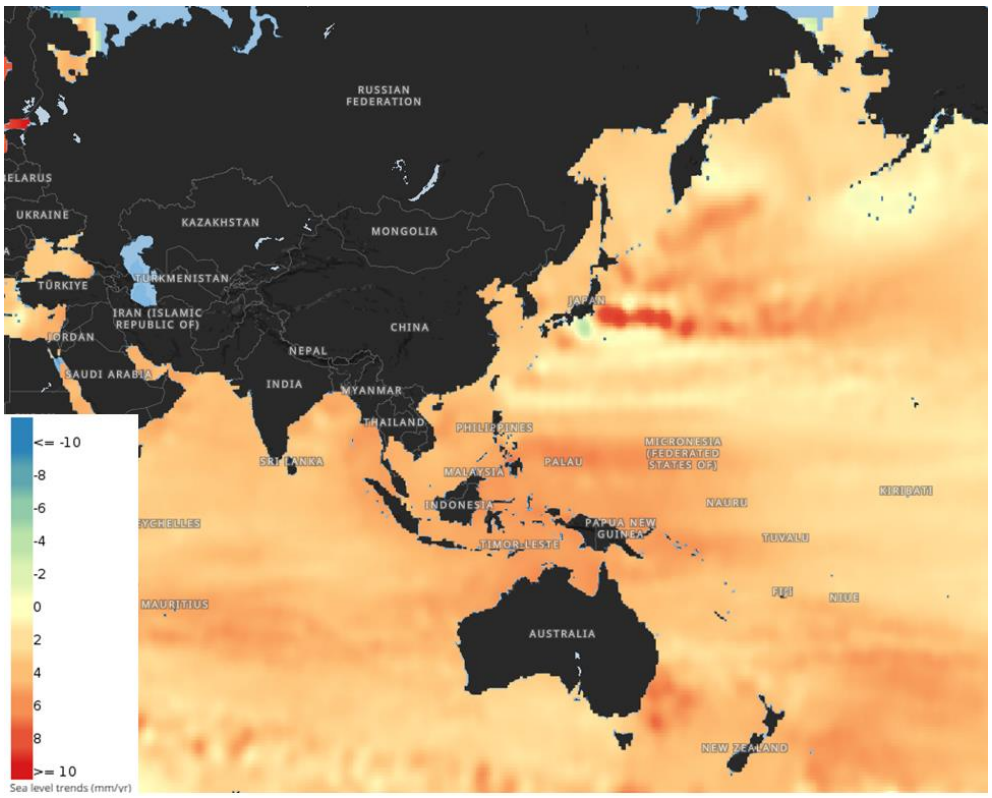

Figure 26 Trends in sea level rise (mm/year) since 1993 in the Asia and Pacific region
Source: The map is drawn from the MapX (UNEP-GRID, 2023)

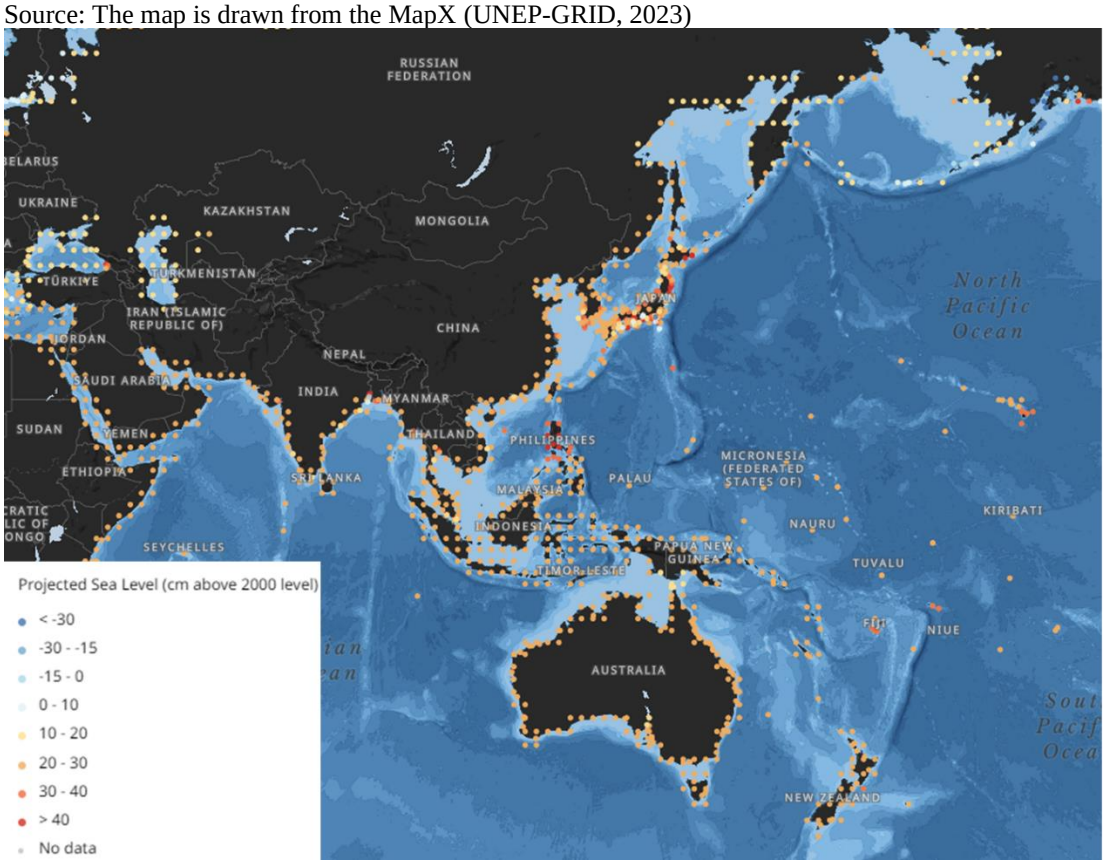

Figure 27 Projected sea level rise (mm/year) for 2050, projected sea level (cm above the 2000 level) in the Asia and Pacific region
Source: The map is drawn from the MapX (UNEP-GRID, 2023)

Annex II: Dynamics of Mangroves Restoration in the Region

Adaptation measures have the potential to counteract the expected losses in mangroves and enhance their ability to withstand and recover from the impacts of climate change. Coastal planning can be adjusted to accommodate mangrove migration as sea levels rise. Additionally, managing activities within the catchment that influence long-term trends in mangrove sediment elevation, improved management of other stressors on mangroves, rehabilitation of degraded mangrove areas, and the development of well-designed protected area networks that incorporate mangroves and interconnected ecosystems through representation, replication, and refugia, are all viable options for adaptation (Gilman et al., 2008).

Restoring mangroves is a crucial and high-priority endeavour due to the wide array of indispensable advantages they offer to people, ecosystems, and biodiversity. Mangroves possess the natural ability to recolonize suitable environments, making restoration efforts particularly effective when they concentrate on creating conditions conducive to their reestablishment and growth (FAO, 2023). The mangrove cover loss maps between 1996 – 2020 can be used to estimate potential restoration areas by removing the permanent land use change or eroded areas.

The Asia Pacific region has half of the world's remaining mangroves, including the Sundarbans, the world's largest mangrove forest, located in the Ganges-Brahmaputra Delta in the Bay of Bengal (Giri et al., 2011). Mangroves provide several important ecosystem services, such as carbon sequestration, shoreline stabilization, sediment accumulation, and coastal protection. Mangrove ecosystems in the Asia-Pacific region are highly diverse and vital for supporting rich biodiversity. They provide essential services such as provisioning, regulation, and support, which are crucial for the livelihoods of local communities. Mangroves and intertidal habitats act as protective buffers, preventing siltation and benefiting offshore coral reefs and seagrass beds, underscoring the interconnectedness of coastal ecosystems in the region.

Over the last decade, a growing number of climate adaptation and ‘blue carbon’ related initiatives have promoted mangrove restoration programs across Pacific countries. Restoring mangroves is a crucial and high-priority endeavour due to the wide array of indispensable advantages they offer to people, ecosystems, and biodiversity. Mangroves possess the natural ability to recolonize suitable environments, making restoration efforts particularly effective when they concentrate on creating conditions conducive to their reestablishment and growth. Mangrove restoration efforts have played a significant role in expanding mangrove areas in Asia over the past 20 years. In East Asia, restoration accounted for the entire gain in mangrove areas, while in South and Southeast Asia, restoration contributed about one-quarter of the observed gain (FAO, 2023).

China is developing a green wall of mangroves along its coasts by planning to create and restore over 18,000 hectares of mangrove forest by 2025. To become one of the countries with a net gain in mangroves (WEF, 2023). To empower mangrove conservation actions, the “China Mangrove Conservation and Restoration Strategy Research Project” was initiated in 2018. Over the past two decades 8,000 hectares of mangrove forest have been restored (Paulson

Institute et al., n.d.) and 67% of mangrove forests in the country were enclosed within protected areas (CIP, 2023). In 2020, the national government of Indonesia announced its aim to rehabilitate 600,000 ha of mangroves between 2020 and 2024 (Sasmito et al., 2023).

Mangrove restoration is often unsuccessful because it focuses too much on replanting mangrove seedlings, particularly in unsuitable habitats, poor site–species matching; a lack of maintenance; inadequate assessment and control of barriers to mangrove recovery; and a lack of support from and participation by local communities in restoration efforts. In the Philippines, the long-term survival rates of mangrove plantings have been as low as 10-20%. In Sri Lanka, 40% of restored mangrove sites failed, and only 20% were successful (FAO, 2023).

Mangrove restoration projects are underway in many countries in the Asia Pacific region, including the Philippines, Thailand, Viet Nam, India, Pakistan, Bangladesh, Sri Lanka, Myanmar, Australia, and some Pacific Islands. These projects are being implemented by a variety of government and non-government organizations, and they focus on replanting mangrove trees, raising awareness about the importance of mangrove conservation, and protecting mangrove forests from threats such as aquaculture and development. These are just a few examples of the many efforts that are underway to restore mangrove ecosystems in the Asia Pacific region. These efforts are essential to protect these valuable ecosystems and the benefits they provide to people, ecosystems, and biodiversity.

Annex III: The Seas of East Asia and the Coastal Ecosystem in the Asia Pacific

The Seas of East Asia support 30% of the world's coral reefs and one-third of the world's mangroves.

The Coordinating Body on the Seas of East Asia (COBSEA) is making significant progress on several important marine conservation and management issues. The ongoing projects and key achievements demonstrated by the COBSEA's commitment to protecting the East Asian Seas and its valuable marine resources relevant to coastal ecosystems includes National Assessment Reports on sea-level rise and coastal erosion in the East Asian Seas , Revised COBSEA Regional Action Plan on Marine Litter adopted in 2019, and COBSEA's Regional Resource Document on Coastal and Marine Spatial Planning; while there are three notable on gong projects are SEA circular: A regional project to reduce marine litter and plastic pollution through better management of the plastic value chain, Marine and Coastal Spatial Planning (MCSP): A project to advance MCSP in the East Asian Seas by building capacity and supporting development of a conducive policy environment, and Two UNEP GEF projects: One to implement the Strategic Action Programme for the South China Sea, and one to establish a regional system of fisheries refugia in the South China Sea and Gulf of Thailand (Mead, 2021; UNEP, 2023b).

Annex IV: Maps of Distribution of Coral Reefs at Risk in the Asia Pacific

The following figures depict the spatial distribution of coral reefs at risk for the present scenario and the predicted scenario by 2050 for the Asia Pacific region and the target countries (Indonesia, Bangladesh, Maldives, and Samoa).

Figure 28 shows the distribution of categories of coral reefs at risk from the integrated local and global threats projected from 2050 in the Asia Pacific region. Figure 29 depicts the distribution of categories of coral reefs at risk from the integrated local threats in the Asia Pacific region. Figure 30 and Figure 31 indicate the distribution of categories of projected coral reefs at risk in the target countries – a) Indonesia, b) Bangladesh, c) Maldives, and d) Samoa

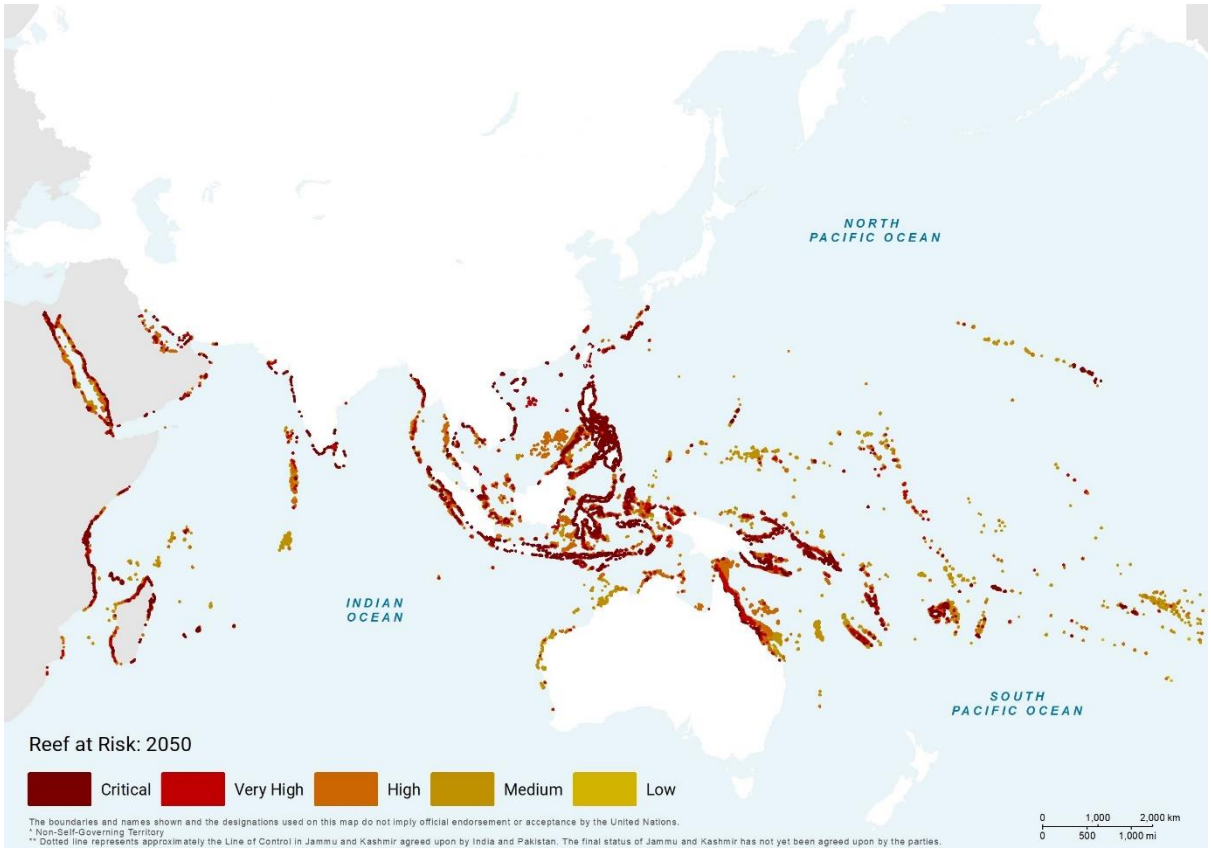

Figure 28 Distribution of categories of coral reefs at risk from the integrated local and global threats projected from 2050 in the Asia Pacific region (Burke et al., 2011).
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, and damage, Overfishing and destructive fishing. Global threats covered Thermal stress (warming sea temperatures, which can induce coral bleaching) and Ocean acidification (driven by increased CO2, which can reduce coral growth rates) (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

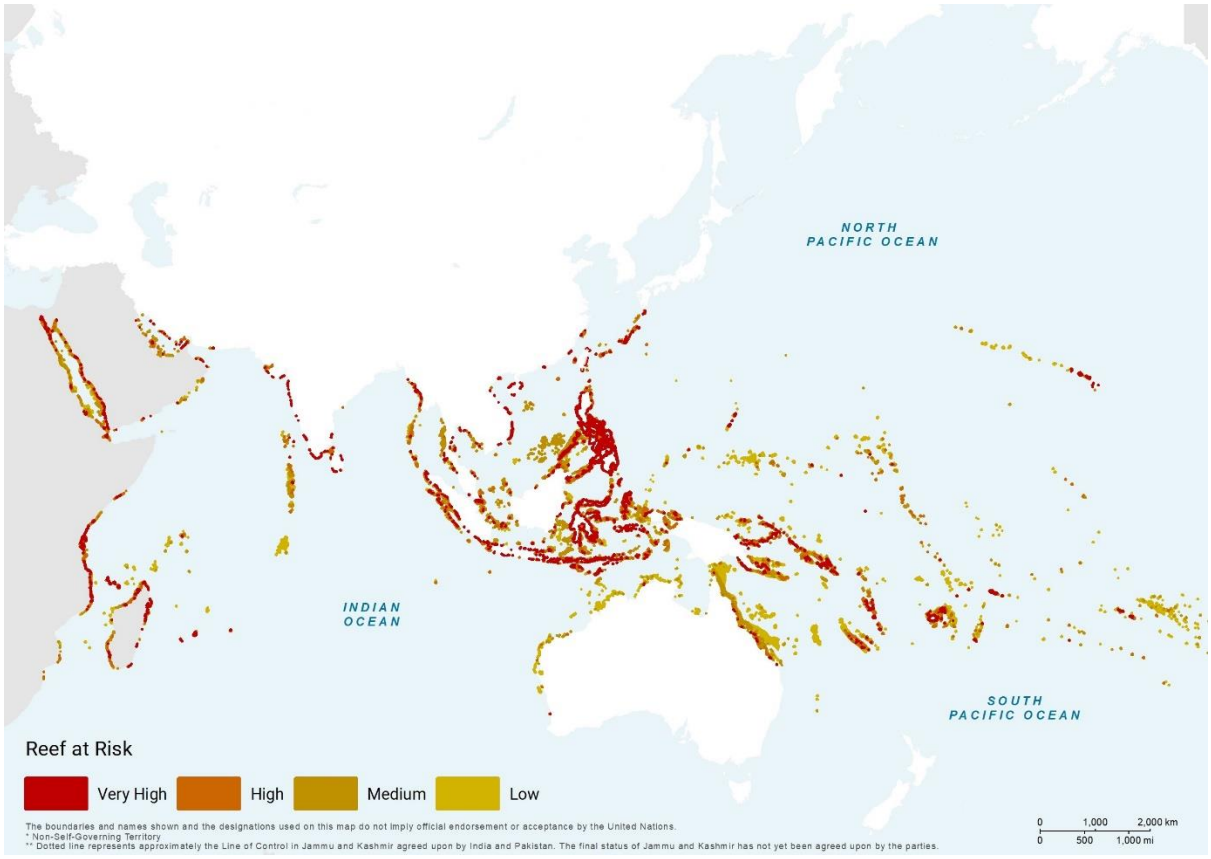

Figure 29 Distribution of categories of coral reefs at risk from the integrated local threats in the Asia Pacific region (Burke et al., 2011).
The analysis is based on the quantification and mapping of threats to the world's coral reefs incorporating more than 50 datasets related to human pressure in coral reefs. Local threats addressed in this analysis included Coastal development, Watershed-based pollution, Marine-based pollution, damage, Overfishing and destructive fishing (Burke et al., 2011).
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

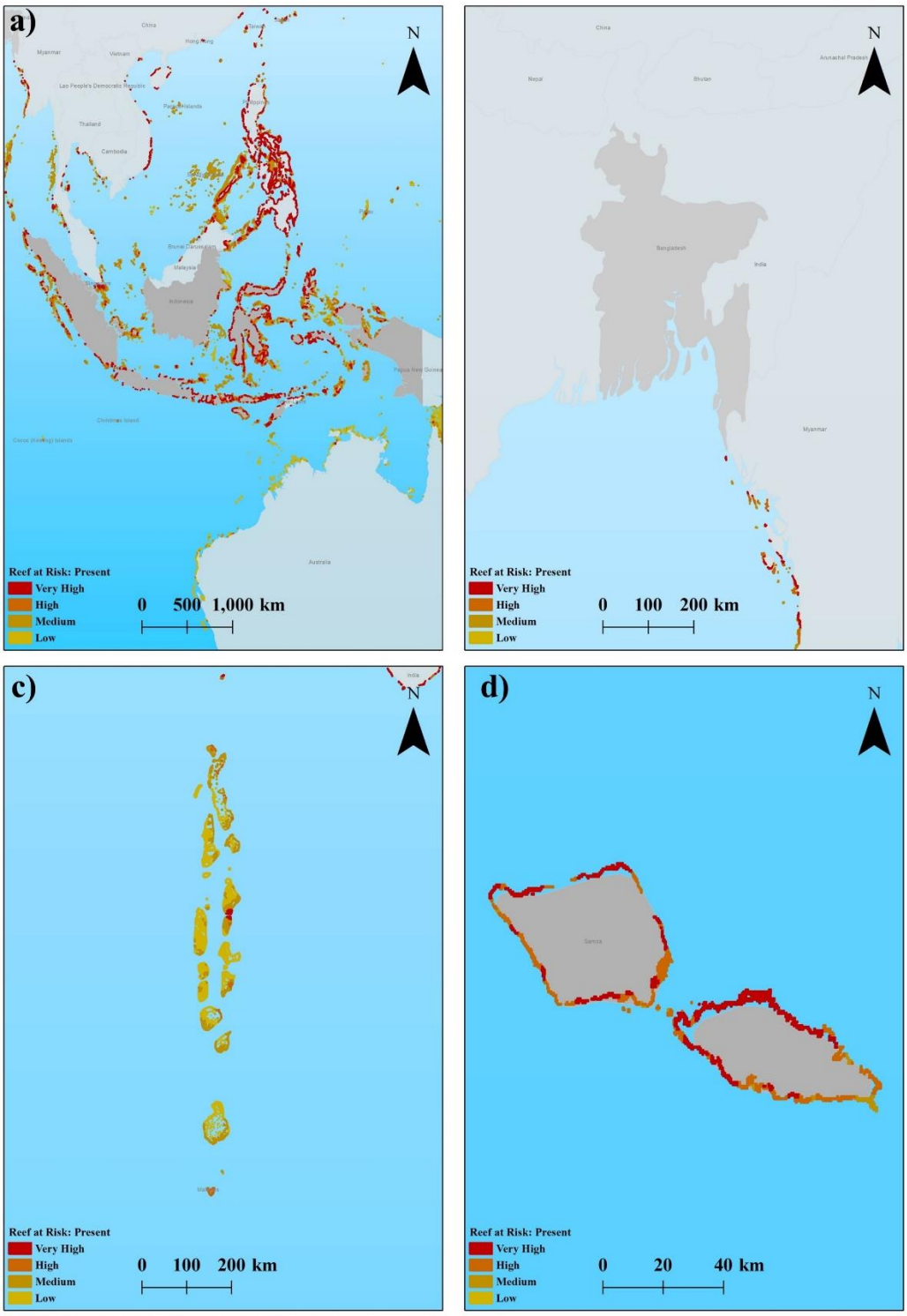

Figure 30 Distribution of categories of coral reefs at risk in the target countries – a) Indonesia, b) Bangladesh, c) Maldives, and d) Samoa. For more details, please refer to chapter 3.
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

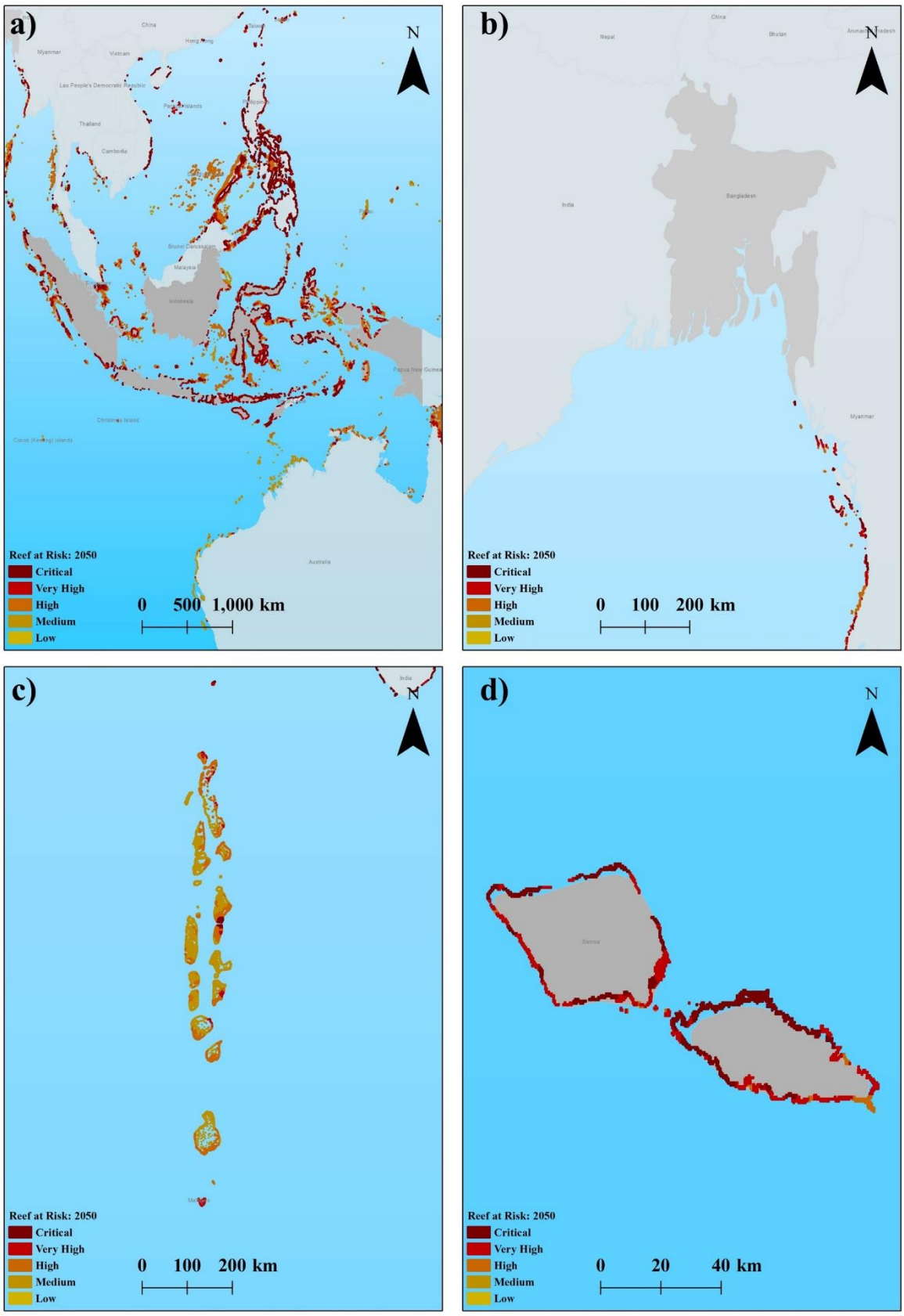

Figure 31 Distribution of categories of projected coral reefs at risk by 20530 in the target countries – a) Indonesia, b) Bangladesh, c) Maldives, and d) Samoa. For more details, please refer to chapter 3.
Source: Authors compilation from (Burke et al., 2011), https://www.wri.org/research/reefs-risk-revisited

Annex V: State of Forest in the Asia Pacific

Forest ecosystems are the largest terrestrial carbon sink and play a significant role in the global carbon cycle. Trends in status and knowledge on forest carbon pools are essential to devise effective and informed policies to preserve forest resources and combat the adverse effects of climate change.

The total global forest area is 4.06 billion hectares (about 31 % of the global land area) in 2020, of which 40% is in the Asia Pacific. Contrary to the global forest cover loss of 47.4 million hectares between 2010 and 2020, the forest cover in the Asia Pacific increased by 0.97% (15.2 million ha) from 1.577 billion hectares in 2010 to 1.592 billion hectares in 2020. The region has lost 14.35 million hectares (~0.9%) of the forest during the last decade, between 2010 - 2020. However, there was a significant increase in the forest cover, 29.6 million hectares (1.87 %), making a net gain in forest cover in the region (FAO, 2020).

The Forest Resources Assessment (FRA) by the FAO provides comprehensive, consistent and reliable information on the state of the forest at global, regional, and national levels to fulfil the needs of society and support the work of various institutions including, the Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCC), United Nations Convention to Combat Desertification (UNCCD), and the Global Forest Goals (GFG) of the United Nations Strategic Plan for Forests, 2017-2030 (UNSPF).

The most recent assessment of the forest resources, FRA 2020, indicate a 31.3 million hectare gain in forest cover of the Asia-Pacific Forestry Commission (APFC) member counties between 1990 and 2020, out of which 13.8 million hectares (44%) forest cover is increased in the most recent decade (2010 to 2020). The total forest area in APFC member countries in 2020 was 751 million hectares, 18.5 % of the global forest area. The increase in forest cover in the region is contrary to the global forest cover loss of 47.4 million hectares during the last decade. However, the gain in the APFC is not uniform across the region – forest increased in nine member countries (Australia, Bhutan, China, Fiji, India, Nepal, New Zealand, Thailand, and Viet Nam) while 17 countries reported a decline in forest cover. China, Australia, Indonesia, and India are among the ten countries with the largest forest area, globally (APCF, 2022; FAO, 2020).

Among APFC member countries, 107.1 million hectares have been lost to deforestation since 1990. However, as with the rest of the world, the annual rate of forest loss has declined substantially in the region from 4.7 million hectares per annum in the 1990-2000 period, to 2.2 million hectares per annum in the most recent five-year period to 2020. However, the loss of primary forests remains a concern in the region. While the area of deforestation in APFC member countries has been more than offset by areas of forest expansion, overall forest biodiversity in the region has likely been reduced because of deforestation and increased share of planted forests as compared to naturally generated/regenerated forests (APCF, 2022; FAO, 2020).

Globally, the area of planted forests has expanded rapidly; from 73.2 million hectares in 1990 to 134.4 million hectares in 2020, an increase of 83.6 %. A significant proportion (46 %) of the

world's planted forests are in the APFC member countries. The area of naturally regenerating forests declined from 649 million hectares in 1990 to 619 million hectares in 2020. Only seven countries (Bhutan, China, Fiji, India, Japan, Nepal, and Viet Nam) reported increases in the area of naturally regenerated forests in the period 1990-2020 (APCF, 2022; FAO, 2020).

Despite an overall increase in forested area in the region since 1990, primary forests continue to decline in Asia and the Pacific. Among the 19 APFC member countries that reported on primary forest area to FRA 2020 primary forest area totals 86.1 million hectares, or 17.1 %. of the forest area in those countries. This is much lower than the global average of 32 %. Among the 18 APFC member countries that have reported primary forest statistics for the complete time series (1990-2020) of the FRA, the primary forest area has declined by 15 %.

Primary forests and natural landscapes in the Asia Pacific are facing increasing pressure due to natural and anthropogenic threats including drought, heatwaves, fires, storms, population dynamics, urbanization, conflicts, economic growth and expansion of agriculture and forest plantations. The impacts of these intricate and interrelated threats are becoming more severe as a result of climate change; in a negative feedback loop, the impacts of climate change are also its drivers when it comes to these threats to primary forests and landscapes. Despite an increase in forest cover, the per-capita forest has decreased from 0.38 to 0.34 over the last decade. Therefore, the demand for food, feed and wood will grow significantly due to both population and economic growth, which will exert additional pressure on primary forests (Y. et al., 2022).

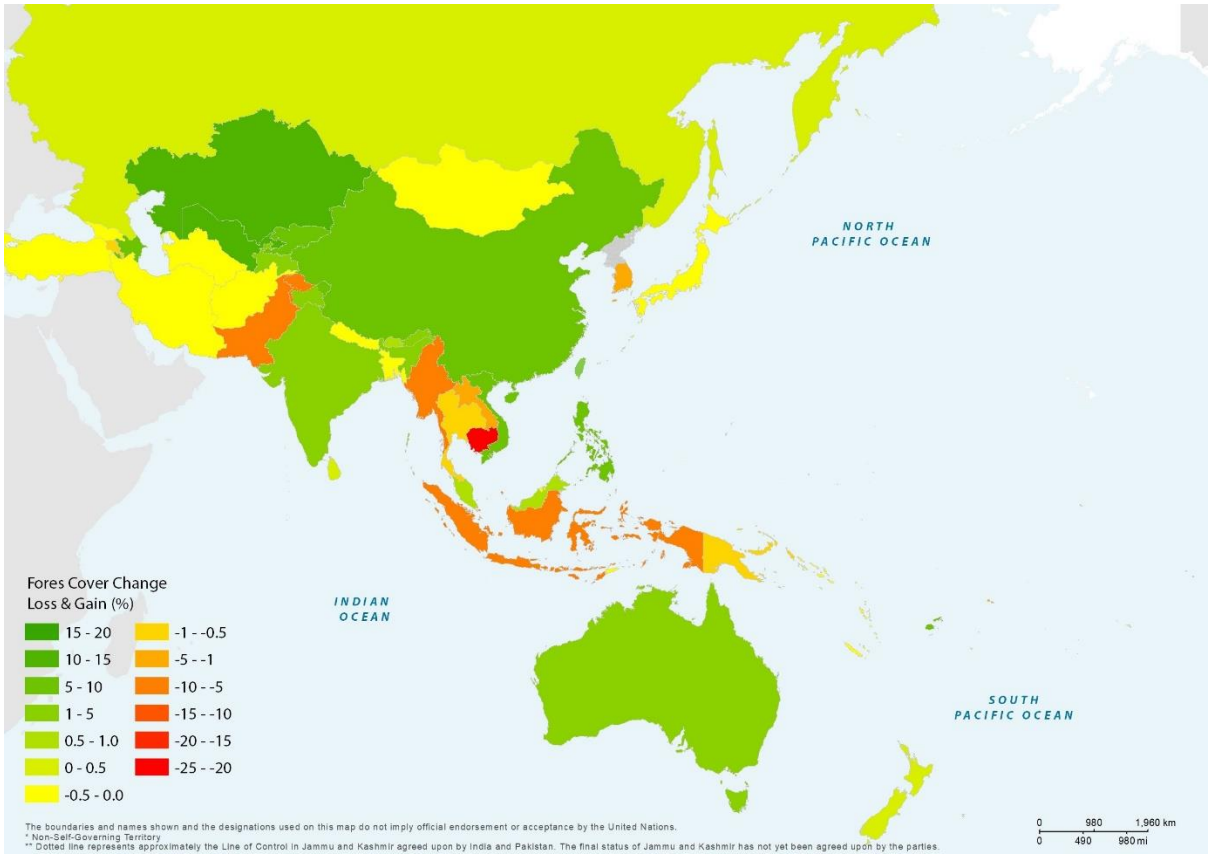

Figure 32. Net change indicating loss or gain in forest cover between 2010 and 2020 in the ESCAP countries.

The data is extracted from the Forest Resources Assessment (FRA) of 2020 by the FAO. The assessment is based on two primary sources of data: i) country reports prepared by national correspondents and ii) remote sensing that is conducted by FAO together with national focal points and regional partners (FAO, 2020). *"FRA is a country-driven process, which is based on official statistical data reported to FAO by Members. The work of FRA is guided by the FAO's governing and statutory bodies"*(APCF, 2022).
Source: Authors compilation from (FAO, 2020), *https://data.apps.fao.org/catalog/dataset/forest-area-1990-2020-1000-ha*

The world's total forest growing stock is estimated at 557 billion m^3. The growing stock varies significantly across the globe, with a higher average grow stock value of naturally regenerating forests (140 m^3/ha) than plantation forests (110 m^3/ha) (FAO, 2020). The average growing stock volume of the Asia and Pacific region is about 100 m^3/ha, totalling ~159.2 billion m^3, ~28% of the global value of growing carbon stock in 2020.

In Asia, the forest growing stock has increased from 95.3 m^3 to 100.4 m^3 in the last decade (2010-2020) (FAO, 2020). With the total net losses in forest cover of 14.35 million ha during the last decade, the region has lost almost 2 Gt of growing stock. The region has also increased in forest cover, a total net gain of 29.5 million ha, which could yield 3 Gt of growing stock. However, growing stock Asia has the highest proportion of growing stock of planted forest which is yet to achieve high volumes of growing stock.

Live biomass is decreasing, despite expanding forest area, overall.

The amount of living biomass of the global forest cover is 606 gigatonnes, with an average value of 149.3 tonnes per hectare (FAO, 2020).

The per hectare average value of forest biomass in the Asia Pacific region is 140 tonnes, totalling 222 Gt of live biomass in the region, ~36 % of the global value of growing carbon stock in 2020.

In the Asia Pacific, accumulated per hectare average carbon in living biomass, dead wood and litter, and soil is ~157.3 tonnes, totalling 250 Gt of live biomass in the region, ~37 % of the tonnes of global carbon stock in 2020.

Some areas are increasing carbon stocks in forests, despite the overall decline, regionally and globally.

The amount of total carbon stock of global forests is 662 Gt, with an average value of 163 tonnes per hectare *(FAO, 2020)*. The per hectare average value of forest biomass in the Asia Pacific region is 157.25 tonnes, totalling 250 Gt of total forest carbon stock in the region, comprising 108 Gt in living biomass, 120 Gt in soil organic matter, and 22 Gt in dead wood litter.

Box 1 Carbon stock, biomass stock, and Growing carbon stock

Growing stock is the total volume of living trees in a forest. It is a measure of the forest's wood resources and is expressed as the volume of wood per unit area. Growing stock can be used to assess how well or poorly stocked a forest is and to estimate the amount of wood that can be harvested sustainably (FAO, 2020).

Biomass stock is all the biomass of living vegetation, both woody and herbaceous, above and below the soil. It includes all parts of the plant, such as stems, stumps, branches, bark, seeds, foliage, and roots. Biomass stock is important because it can be used to produce a variety of renewable energy sources and other products (FAO, 2020).

Carbon stock is the total amount of carbon stored in a forest, including all carbon pools, such as soil organic matter, living biomass, and dead wood and litter. Carbon stock is important because forests play a vital role in climate change mitigation by storing carbon dioxide from the atmosphere (FAO, 2020).

Despite reduction at the global level, the forest carbon stock in forest biomass increased significantly in East Asia, Western and Central Asia. The areas with the most loss of carbon stock in the Asia Pacific are Indonesia, Myanmar, and Cambodia, where are carbon stocks declining the most rapidly due to deforestation. On the other hand, the countries with increasing net forest cover in the region include China, Australia, India, and Viet Nam. Most of the forest in the Asia Pacific region is secondary or plantation, which might cause an overall reduction in carbon stock and/or live biomass despite an increase in the net forest cover *(FAO, 2020)*. It may be assumed that the current volume of growing stock and/or live biomass in the region is overestimated, considering young secondary natural forests or planted forests yet to achieve high volumes of growing stock or live biomass.

With declines in primary forest cover, we expect declining climate resilience and reduced ecosystem services.

Degradation and fragmentation of primary forests reduce the capacity of these forests to provide ecosystem services, including a decline in carbon stocks, and to cope with external climate-related shocks and vulnerability to fire (Table 22) The losses in these ecosystem services will most impact Indonesia, Myanmar, Cambodia, and Pakistan. Therefore, preserving the primary forest could enhance both the services and functionalities of forest ecosystems (FAO, 2020). Hence, reversing these trends and halting primary forest loss and degradation should be a priority for all countries in the region (APCF, 2022; FAO, 2020).

Natural forests store 40 times more carbon than plantations

Restoring natural forests is the best way to store carbon. Natural forests store six times more carbon than agroforestry and 40 times more carbon than plantations. Allowing forests to

regenerate naturally is the most cost-effective and simple approach. By protecting forests from fire and other human disturbances, trees can return and forests can thrive, rapidly increasing carbon stocks to reach the level of a mature forest in about 70 years. (Poorter et al., 2016)

Carbon Losses and Opportunities for Forest Conservation (nature-based solution) in Southeast Asia

Southeast Asia's tropical forests are under threat from deforestation, which contributes to climate change. Large-scale carbon projects that focus on preventing deforestation can help to mitigate climate change impacts. The region has a vast tropical forest cover of about 196 million hectares. A significant portion of the forest is vulnerable to agricultural expansion and other economic activities (Sodhi et al., 2010). Deforestation in the region is estimated to have released 2.56 Gt CO2e (gigatons of carbon dioxide equivalent) annually between 2005 and 2010, and further losses are likely to worsen climate change impacts (Pearson et al., 2017).

However, there is a significant opportunity to implement large-scale carbon projects that focus on preventing deforestation, a nature-based climate solution. Forest carbon projects can deliver multiple benefits to society. Viable carbon financing projects in the region can protect more than half of the forests threatened by loss. The proposed nature-based solution can avoid deforestation emissions of 835 MtCO2e per year, in addition to other ecosystem services and biodiversity conservation in the region (Sarira et al., 2022).

A recent study (Graham et al., 2021) found that protected areas in Southeast Asia are effective in conserving forest cover and forest carbon stocks compared to unprotected areas. Malaysian and Cambodian protected areas avoided significantly more forest loss than adjacent non-protected control areas, at 15% and 11% respectively. This study provides evidence that protected areas can play a significant role in mitigating climate change and conserving biodiversity in Southeast Asia.

In addition to protected areas, significantly enhanced protection under REDD+ can increase the proportion of deforestation losses, which may be more than the protected areas, while implementing nature-based solutions (Pauly et al., 2022).

CO2 emission from deforestation in the Asia Pacific region

The CO2 emissions were very high in the 1990s and have gradually decreased over the last two decades (

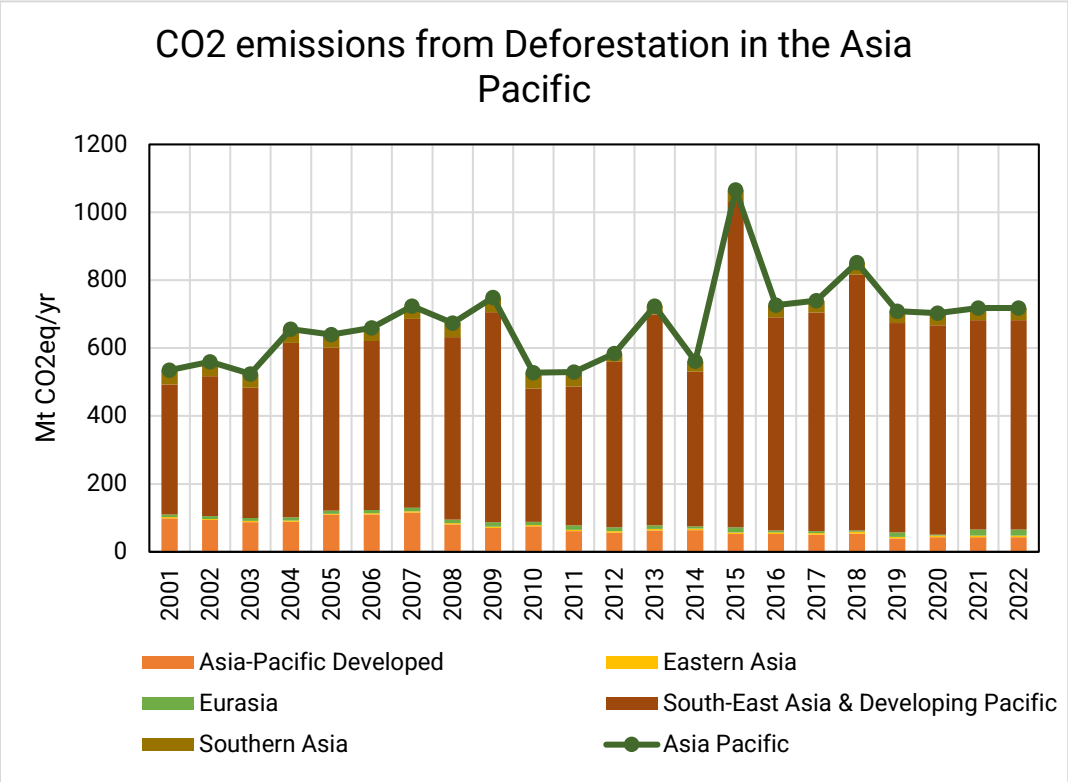

Figure 33). However, there has been a slight increase in emissions during the last decade compared to the earlier decade 2000-2010. In the recent five years, 2019- 2020 the emissions from deforestation have been area relatively stable in the region indicating a reduction in the rate of deforestation. The CO2 emissions from deforestation have decreased from 1282 Mt CO2eq / yr in 1990 to 718 Mt CO2eq / yr in 2020. The most significant proportion of the emissions comes from the Southeast Asia and Pacific region (Crippa et al., 2023; EDGAR, 2023; IEA-EDGAR, 2023).

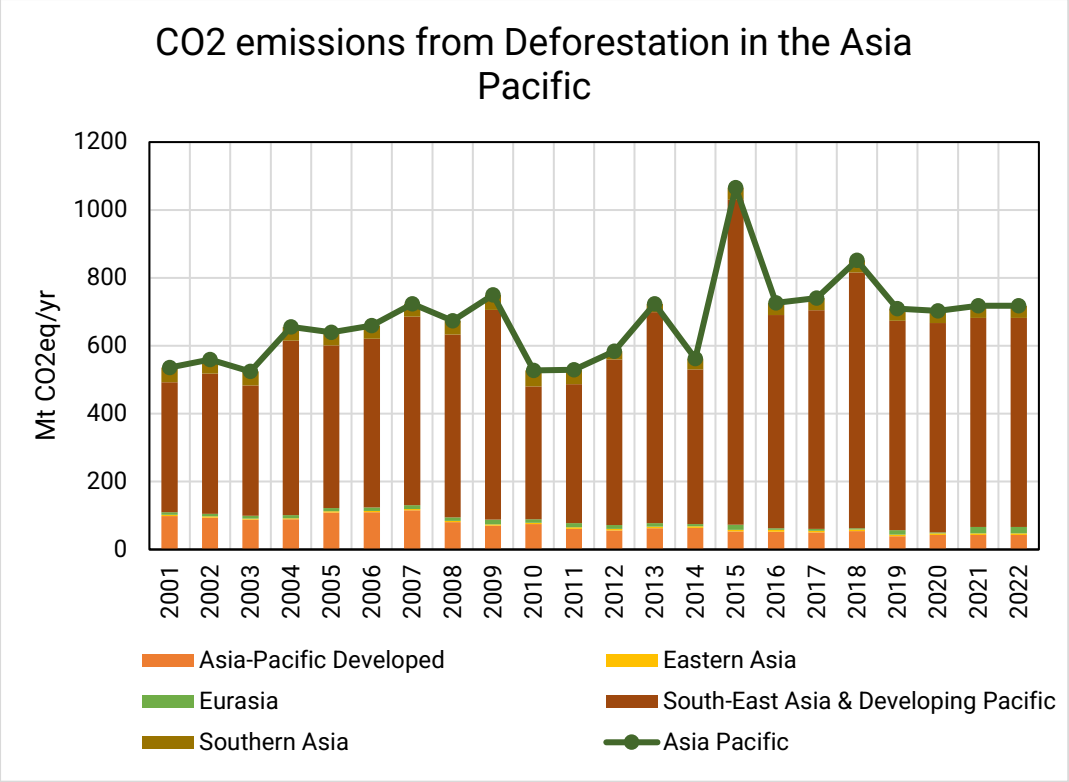

Figure 33. CO2 emissions from deforestation in the Asia Pacific region

Source: Author's compilation from (Crippa et al., 2023; EDGAR, 2023; IEA-EDGAR, 2023) https://edgar.jrc.ec.europa.eu/dataset_ghg70#p1

Key Message

Overall forest cover in the Asia Pacific region has increased, contrary to the decline in global forest cover.

The total global forest area reached 4.06 billion hectares, with the Asia Pacific region accounting for 40% of this vast expanse. Over the decade from 2010 to 2020, the world experienced a net loss of 47.4 million hectares of forest. However, the Asia Pacific region managed to gain 15.203 million hectares of forest cover during the same period. This increase is primarily attributed to substantial growth in the forest stock in China, Japan, and the Republic of Korea, all of which have implemented extensive reforestation initiatives in recent years.

Asia Pacific accounts for one-third of the global forest carbon stock

The Asia and Pacific region, with an average growing stock volume of approximately 100 m3/ha, boasts a substantial total of about 159.2 billion m3, constituting around 28% of the global carbon stock in growing forests as of 2020. Furthermore, the region is a significant contributor to global carbon stock, accounting for 37% (250 Gt) of the world's total carbon

stock of 662 Gt in 2020. Despite the overall increase in forest cover, per-capita forest area and per-capita forest carbon stock have declined over the past decade.

Declining primary forest and monocultural plantations might be a concern for long-term carbon sequestration potential in the region.

It's worth noting that the current volume of growing carbon stock in the region may be overestimated due to a high proportion of secondary or plantation forests. Natural forests, in contrast, store significantly more carbon than plantations, and it takes 70 years for naturally regenerating forests to reach the carbon level of mature forests. The decline in naturally regenerating forests in the region from 1990 to 2020, alongside degradation and fragmentation of primary forests, is impacting the ability of these ecosystems to provide essential services and adapt to external shocks. Preserving primary forests and facilitating their natural regeneration can enhance the functionality of forest ecosystems, including climate resilience and carbon capture and storage.

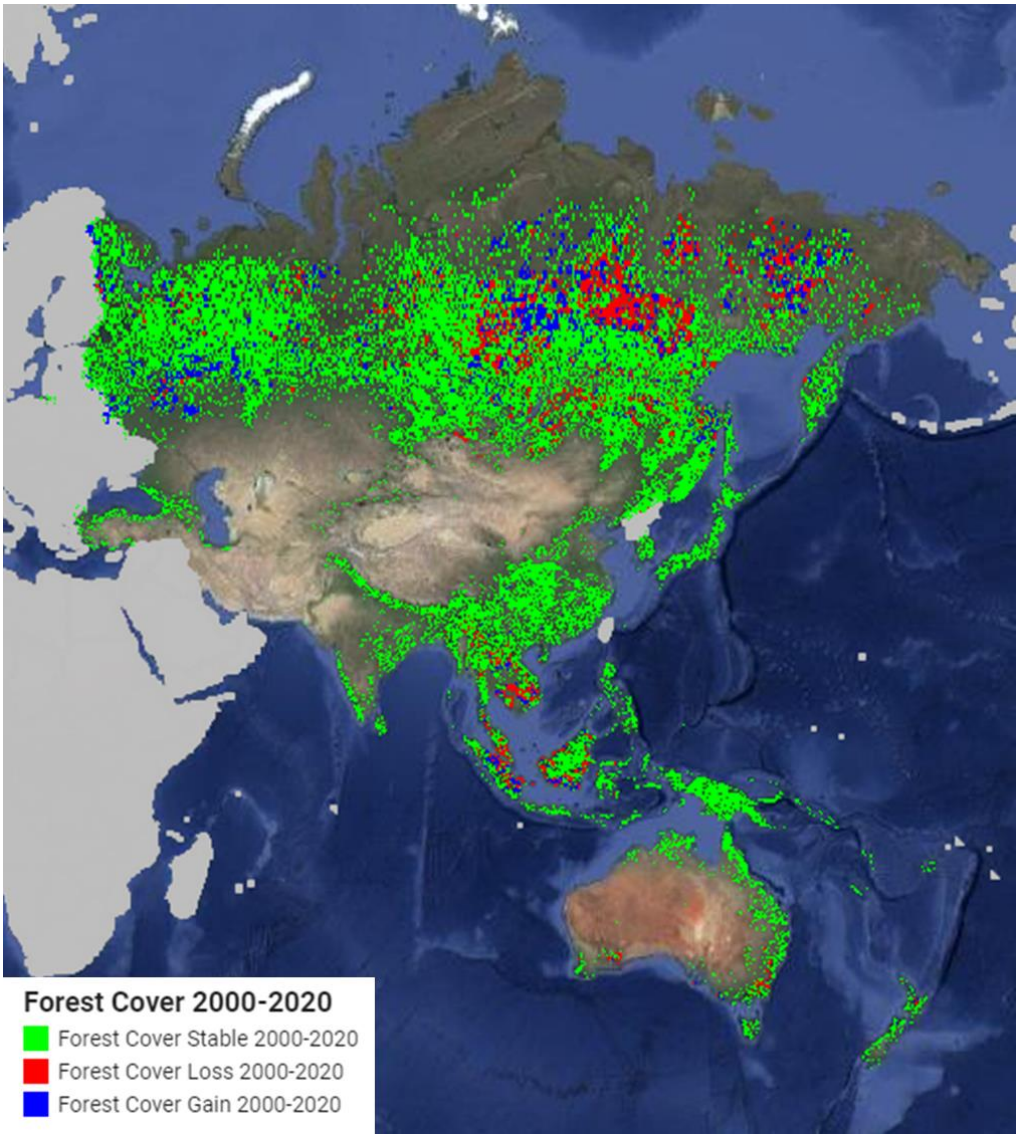

Figure 34. Spatial patterns of forest cover, gains and losses between 2000 and 2020 in the Asia-Pacific region derived from the (Hansen et al., 2013).
Source: Author's compilation from (Hansen et al., 2013) *using the Google Earth Engine* (Gorelick et al., 2017), *"projects/glad/GLCLU2020/Forest_type", https://glad.umd.edu/dataset/GLCLUC2020*
"In this dataset, the forest extent maps for the years 2000 and 2020 were produced by attributing with ≥ 5 m forest height as the "forest" land cover class, to ensure consistency with the FAO FRA forest definition (www.fao.org/3/I8661EN/i8661en.pdf). The forest extent change (net forest extent loss and gain) was derived directly from the years 2000 and 2020 map comparison. However, the forest definition differs from the one used by the FAO by the inclusion of trees outside forests (agroforestry, orchards, parks) and the exclusion of temporally unstocked forest areas. (https://storage.googleapis.com/earthenginepartners-hansen/GFC-2020-v1.8/download.html)"

Table 21 Forest cover area in the ESCAP countries.
The data is extracted from the Forest Resources Assessment (FRA) of 2020) by the FAO. The assessment is based on two primary sources of data i) country reports prepared by national correspondents and ii) remote sensing that is conducted by FAO together with national focal points and regional partners (FAO, 2020). *"FRA is a country-driven process, which is based on official statistical data reported to FAO by Members. The work of FRA is guided by the FAO's governing and statutory bodies".* (APCF, 2022) .
Data Source: https://data.apps.fao.org/catalog/dataset/forest-area-1990-2020-1000-ha

	2010	2020	Loss/Gain	Loss/Gain %
Country		1000 ha		
Afghanistan	1208.44	1208.44	0	0
American Samoa	17.43	17.13	-0.3	-1.72117
Armenia	330.56	328.47	-2.09	-0.63226
Australia	129,546.10	134,005.10	4459	3.442018
Azerbaijan	1032.49	1131.77	99.28	9.615589
Bangladesh	1888.34	1883.4	-4.94	-0.26161
Bhutan	2705.29	2725.08	19.79	0.73153
Brunei Darussalam	380	380	0	0
Cambodia	10,589.23	8068.37	-2520.86	-23.8059
China	200,610.38	219,978.18	19367.8	9.654436
Cook Islands	15.59	15.59	0	0
Fiji	1073.24	1140.02	66.78	6.22228
French Polynesia (Desk study)	149.46	149.46	0	0
Georgia	2822.4	2822.4	0	0
Guam	24	28	4	16.66667
India	69,496	72,160	2664	3.833314
Indonesia	99,659.20	92,133.20	-7526	-7.55174
Iran (Islamic Republic of)	10,691.98	10,751.87	59.89	0.560139
Japan	24,966	24,935	-31	-0.12417
Kazakhstan	3082.18	3454.68	372.5	12.0856
Kiribati (Desk study)	1.18	1.18	0	0
Kyrgyzstan	1229.68	1315.38	85.7	6.969293
Lao People's Democratic Republic	16,940.50	16,595.50	-345	-2.03654
Malaysia	18,947.65	19,114.04	166.39	0.878156
Maldives	0.82	0.82	0	0
Marshall Islands	9.4	9.4	0	0
Micronesia (Federated States of)	64.13	64.42	0.29	0.452206
Mongolia	14,183.90	14,172.78	-11.12	-0.0784
Myanmar	31,441	28,543.89	-2897.11	-9.21443
Nauru (Desk study)	0	0	0	#DIV/0!
Nepal	5962.03	5962.03	0	0
New Zealand	9848.12	9892.59	44.47	0.451558
Northern Mariana Islands	30.32	24.36	-5.96	-19.657
Pakistan	4093.73	3725.9	-367.83	-8.9852
Palau	40.56	41.41	0.85	2.095661
Palestine (Desk study)	9.95	10.14	0.19	1.909548
Papua New Guinea	36,178.89	35,855.76	-323.13	-0.89315
Philippines	6839.72	7188.59	348.87	5.100647
Republic of Korea	6387	6287	-100	-1.56568
Samoa	166.49	161.67	-4.82	-2.89507

Singapore	17.74	15.57	-2.17	-12.2322
Solomon Islands	2530.28	2522.97	-7.31	-0.2889
Sri Lanka	2103.62	2113.02	9.4	0.446849
Tajikistan	410	423.8	13.8	3.365854
Thailand	20,073	19,873	-200	-0.99636
Tonga	8.95	8.95	0	0
Turkmenistan (Desk study)	4127	4127	0	0
Tuvalu	1	1	0	0
Uzbekistan	3349.6	3689.66	340.06	10.15226
Vanuatu	442.3	442.3	0	0
Viet Nam	13,388.06	14,643.09	1255.03	9.374248
Russian Federation	815,135.60	815,311.60	176	0.021591
New Caledonia (Desk study)	839.02	838.02	-1	-0.11919
Total Forest in ESCAP	**1577099.6**	**1592313**		
Total Loss in ESCAP (2010-2020)	**-14350.64**	-0.909938754		
Total Gain in ESCAP (2010-2020)	**29554.09**	1.873952091		
Net Gain/Loss in ESCAP (2010-2020)	**15203.45**	**0.964013337**		

Table 22 Primary Forest cover area in the ESCAP countries.
The data is extracted from the Forest Resources Assessment (FRA) of 2020) by the FAO. The assessment is based on two primary sources of data i) country reports prepared by national correspondents and ii) remote sensing that is conducted by FAO together with national focal points and regional partners (FAO, 2020). *"FRA is a country-driven process, which is based on official statistical data reported to FAO by Members. The work of FRA is guided by the FAO's governing and statutory bodies".* (APCF, 2022) .
Data Source: https://fra-data.fao.org/assessments/fra/2020/OC/home/overview/

Country	**2000**	**2010**	**2020**	**Gain/Loss 2000-2020**	**Gain/Loss 2010-2020**
			1000 ha		
Armenia	17	17	17	0	0
Brunei Darussalam	288	263	263	-25	0
Cambodia	456	322	322	-134	0
China	11453	11453.33	11453.33	0.33	0
Georgia	500	500	500	0	0
India	15701	15701	15701	0	0
Indonesia	52728	45597	44740	-7988	-857
Iran	200	200	200	0	0
Japan	4054	4770	5346	1292	576
Kazakhstan	31.8	30.5	66.9	35.1	36.4
Kyrgyzstan	437.2	455.2	487	49.8	31.8
Malaysia	1086.16	1086.16	1086.16	0	0
Myanmar	3192	3192	3192	0	0
Nepal	548	526	526	-22	0
Philippines	861	861	861	0	0
Sri Lanka	197	167	167	-30	0
Tajikistan	296	296	296	0	0
Turkmenistan (Desk study)	104	104	104	0	0
Uzbekistan	210.3	210.3	210.3	0	0
Viet Nam	187	80	80	-107	0
American Samoa	5.3	2.69	0.09	-5.21	-2.6

Australia	4963			-4963	0
French Polynesia (Desk study)	40	40	40	0	0
Marshall Islands	5.76	5.76	5.76	0	0
Micronesia (Federated States of)	43.97	48.37	48.37	4.4	0
New Zealand	2127	2152	1971	-156	-181
Tonga	4	4	4	0	0
Tuvalu	0	0	0	0	0
Vanuatu	205	205	205	0	0
Total Primary Forest in ESCAP	99941.49	88289.31	87892.91	-12048.58	-396.4
Net Gains and Losses in the ESCAP 2000-2020					
Loss of Primary Forest in ESCAP 2000-2020			-13430.21		
Gain in Primary Forest in ESCAP 2000-2020			1381.63		
Net Loss in ESCAP 2000-2020			-12048.58		
Net Gains and Losses in the ESCAP 2010-2020					
Loss of Primary Forest in ESCAP 2010-2020			-1040.6		
Gain in Primary Forest in ESCAP 2010-2020			612.4		
Net Loss in ESCAP 2010-2020			-396.4		

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