

Review

Leveraging mangroves to advance climate action in Africa: Zooming in on Nationally Determined Contributions (NDCs)



Samuel Appiah Ofori ^{a,b,*}, Jean Hugé ^{a,c,d}, Setondé Constant Gnansounou ^{e,f}, Arimatéa C. Ximenes ^g, Frederick Asante ^h, M'koumfida Bagbohoua ⁱ, Adrien Comte ^j, Esméralda Longépée ^k, Kipkorir Sigi Lang'at ^l, Salomão Olinda Bandeira ^m, Derrick Omollo ^{n,o}, Amarachi Paschaline Onyena ^p, Kabari Sam ^q, Amina Juma Hamza ^r, Adel Zeggaf Tahiri ^s, Daf Sehla Daf ^t, Khady Diouf Goudiaby ^u, Emmanuel Temitope Olatunji ^v, Claire Golléty ^{w,x}, Elie Antoine Padonou ^y, Farid Dahdouh-Guebas ^{a,z,aa,ab}

^a Systems Ecology and Resource Management Research Unit, Department of Biology of Organisms, Université Libre de Bruxelles – ULB, Av. F.D. Roosevelt 50, Cpi 264/1, 1050, Brussels, Belgium

^b Projects Department, One Tree Planted, Shelburne, USA

^c Department of Environmental Sciences, Open University of the Netherlands, the Netherlands

^d bDIV: Ecology, Evolution & Genetics, Department of Biology, Vrije Universiteit Brussel – VUB, Pleinlaan 2, 1050, Brussels, Belgium

^e Department of Geography & Institute of Life, Earth and Environment, University of Namur, Belgium

^f Laboratoire de Biomathématiques et d'Estimations Forestières, University of Abomey-Calavi, Benin

^g Center for International Forestry Research - World Agroforestry (CIFOR-ICRAF), Jl. Situgede, Bogor, 16115, Indonesia

^h Moore Inclusive Conservation Lab, Department of Forest and Conservation Sciences, Faculty of Forestry, University of British Columbia, Forest Sciences Centre (FSC) 2424 Main Mall, Vancouver, BC, V6T 1Z4, Canada

ⁱ Graduate Studies Programme on Climate Change and Education, WASCAL, School of Agriculture and Environmental Sciences, University of The Gambia, the Republic of the Gambia

^j IRD, Univ Brest, CNRS, Ifremer, LEMAR, Plouzané, 29280, France

^k UMR 8586 PRODIG, Université Paris 1 Panthéon-Sorbonne, CNRS, IRD, AgroParisTech, 5, cours des Humanités, F-93 322, Aubervilliers Cedex, Paris, France

^l Kenya Marine and Fisheries Research Institute, P. O. Box 81651, Mombasa, Kenya

^m Department of Biological Sciences, Universidade Eduardo Mondlane, Maputo, Mozambique

ⁿ School of Science, RMIT University, Melbourne, Victoria, 3000, Australia

^o School of Life and Environmental Sciences, Deakin University, Victoria, 3216, Australia

^p Department of Environmental Management and Pollution, Nigeria Maritime University Okerenkoko, Delta State, Nigeria

^q School of the Environment, Geography and Geoscience, University of Portsmouth, Burnaby Road, Portsmouth, PO1 3QL, United Kingdom

^r Oceanography and Hydrography Department, Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100, Mombasa, Kenya

^s Agri. Environ. Engineering, S.A.R.L. Quartier Mojahidine, Rés. Omar-A- no 14, 90000, Tangier, Morocco

^t Diawling National Park (PND), TVZ ILOT 209 et 211, BP3935, Nouakchott, Mauritania

^u Laboratoire de Biologie Marine, Université Cheikh Anta Diop de Dakar, IFAN-Ch. A. Diop, BP, 206, Dakar, Senegal

^v School of Environmental Studies and Climate Change, University of Liberia, P.O Box 10-9020, Capitol Hill, 1000, Monrovia, Liberia

^w MARBEC, Univ Montpellier, CNRS, Ifremer, IRD, Montpellier, France

^x Université de Mayotte, Dembénî, France

^y School of Tropical Forestry, National University of Agriculture, Kétou, Benin

^z Ecology, Evolution & Genetics, Department of Biology, Faculty of Sciences and Bio-Engineering Sciences, Vrije Universiteit Brussel (VUB), VUB-APNA-WE, Pleinlaan 2, B-1050, Brussels, Belgium

^{aa} Mangrove Specialist Group (MSG), Species Survival Commission (SSC), International Union for the Conservation of Nature (IUCN), c/o Zoological Society of London, London, United Kingdom

^{ab} Interfaculty Institute of Social-Ecological Transitions, Université Libre de Bruxelles - ULB, Av. F.D. Roosevelt 50, Cpi 130/03, 1050, Brussels, Belgium

ARTICLE INFO

ABSTRACT

Keywords:

Mangrove-possessing countries

Restoration

Mangroves are vital for climate change adaptation and mitigation due to their efficient carbon sequestration and coastal protection roles providing often untapped opportunities for countries to enhance their national climate commitments (including the so-called Nationally Determined Contributions) under the Paris Agreement adopted

* Corresponding author. Residence Joseph Defaux 46, Gaurain Ramcroix, 7530, Belgium.

E-mail address: Samuel.ofori@ulb.be (S.A. Ofori).

Conservation
Climate action
Mitigation
Adaptation

at the United Nations Framework Convention on Climate Change (UNFCCC) COP21 in 2015. In Africa, several countries possess mangroves and have signed the Paris Agreement, however, the level of integration of mangrove actions into the Nationally Determined Contributions (NDCs) has not been adequately explored.

Using a systematic review methodology, 33 African countries possessing mangroves were selected and their NDCs were reviewed, scored, and ranked to assess their level of integration of mangrove ecosystems into their NDCs.

Countries like Equatorial Guinea, Nigeria, Senegal, and Sudan demonstrate commendable progress and leadership in integrating mangroves within their NDCs. However, gaps in budgetary commitments, spatial planning, and temporal specificity for mangrove actions among a majority of the countries hinder broader mangrove inclusion. The study also revealed a disconnect between research outputs and policy frameworks, where countries with increased mangrove research output in Africa failed to integrate mangrove actions into their NDCs.

To increase African countries' resilience to climate risks and contributions to global climate goals, there is a need to increase effective collaboration between mangrove researchers, local communities, and policymakers in mangrove-possessing countries. This will bolster public education on mangroves and their inclusion of mangrove actions in their NDCs, ultimately enhancing the implementation of mangrove actions on the ground.

1. Introduction

Mangrove ecosystems are recognized as one of the nature-based solutions to a changing climate. They are most efficient in carbon sequestration with a global average total forest stock of 692.8 ± 23.1 ($\pm 1SE$) Mg C_{ORG} ha⁻¹, storing 3–4 times more carbon per equivalent area than terrestrial ecosystems (Donato et al., 2011; Murdiyarsa et al., 2015; Alongi, 2022; Adame et al., 2024). Mangroves can store most (74 %) of their carbon stocks in soils, particularly at the upper 1 m depth (Alongi, 2022). Although mangroves cover only 1.5–1.9 % of the world's tropical and subtropical coastlines, they contribute significantly to carbon storage, accounting for 30 % of carbon stored along low-latitude continental margins (Alongi, 2022; Choudhary et al., 2024).

These data highlight the immense climate change mitigation potential of mangroves, informing coastal countries with mangrove ecosystems of the mitigation benefits they can derive through the management, conservation, and restoration of their mangrove ecosystems (Alongi, 2022). Moreover, in regions where mangrove ecosystems have been degraded due to human activities or natural causes, mangrove restoration (reforestation) is identified to store more carbon than those undertaken in areas where mangroves did not previously occur (afforestation) (Sasmrito et al., 2023; Song et al., 2023).

African mangroves represent 20 % of the world's mangrove cover, potentially contributing largely to the global mangrove carbon storage role (Naidoo, 2023). There is a growing interest in REDD + projects in coastal African countries (a.k.a. blue carbon projects) where public and private organizations from the global North invest in mangrove restoration projects to offset their carbon emissions (Comte et al., 2023). These projects can issue carbon credits to these investors or potential buyers after assessing the amount of carbon stored. The Mikoko Pamoja project in Kenya, recognized as the world's first verified mangrove carbon credit initiative, exemplifies how African countries possessing mangroves can leverage community-led mangrove restoration to achieve their climate change mitigation and adaptation goals (Kairo et al., 2018). With such a high carbon storage potential from African mangroves, it is important to note that Africa records the smallest CO₂ emissions, representing 3.9 % of the global CO₂ emissions (Mostefaoui et al., 2024). These blue carbon projects, while offsetting the carbon emissions of these investors from the global North (Comte et al., 2023), will increase Africa's global carbon mitigation contributions, generate benefits for the communities involved, and promote biodiversity conservation in these mangrove ecosystems.

Mangrove ecosystems are also known to provide climate change adaptation benefits. In the past decades, several reports and research studies have revealed how mangrove ecosystems have served as protective green barriers to coastal communities against environmental hazards such as tsunamis (Dahdouh-Guebas et al., 2005). Mangrove species such as *Sonneratia* spp. and *Avicennia* spp. (with relatively

stronger and taller stems), or *Rhizophora* spp. and *Bruguiera* spp. (with wide prop or knee roots) are known to be able to attenuate wave height by 42 %–47 % by a mangrove belt spanning 246 m wide (Mazda et al., 2006; Horstman et al., 2014). Studies have proven how coastal areas without mangrove ecosystems or having degraded mangrove ecosystems have been impacted more strongly by coastal flooding caused by storm surges, progressive sea-level rise, or tsunamis, triggering mangrove restoration actions in these mangrove-degraded countries (Dahdouh-Guebas et al., 2005; Osti et al., 2011; Kodikara et al., 2017; Dahdouh-Guebas and Cannici, 2021; Zimmer et al., 2022; Sidik et al., 2023).

Amidst the climate change mitigation and adaptation benefits presented by mangrove ecosystems, they are continually being degraded. What is even more alarming is that the global increase in mangrove deforestation rates (Goldberg et al., 2020; Hagger et al., 2022) is recorded in areas that are (supposed to be) protected (Heck et al., 2024). In the IUCN's Red List of Mangrove Ecosystems report (IUCN, 2024), it was revealed that more than half of the world's mangrove ecosystems currently face the risk of collapse by 2050, whereas 16 % of the world's mangrove ecosystems are also projected to be submerged by sea-level rise by 2050. The report also included that the leading causes of the decline in the world's mangroves were deforestation, pollution, and climate change. In recent years, climate change has been a growing threat to mangrove ecosystems, particularly exposing them to more frequent and severe weather events and sea-level rise (IUCN, 2024).

In Africa, mangrove ecosystems are also facing increased threats from human activities and natural factors across the continent. Although the FAO reported a decline in Africa's mangrove ecosystem cover average annual rate of loss from 6610 ha in 1990–2000 to 2330 ha in 2010–2020, the continent is still faced with major drivers of mangrove ecosystem loss in different countries (FAO, 2023). For example, mangrove ecosystems in Nigeria which represents the largest mangrove extent in Africa and third largest in the world is currently faced with issues of oil mining activities, urbanisation, aquaculture, excessive logging, waste disposal, land reclamation, dynamite fishing, and sea-level rise (Naidoo, 2023; Sam et al., 2023). The 2024 State of the World's Mangrove report revealed that Mangroves in the Niger Delta are among the most severely affected in the world by major oil spills (Leal and Spalding, 2024). In countries like Madagascar, Gambia, Guinea-Bissau, Guinea, Liberia, and Côte d'Ivoire, mangrove ecosystem losses are mainly driven by rice farming (Liu et al., 2021; Naidoo, 2023). Over-exploitation of mangrove wood and salt mining has also been a major contributor to mangrove ecosystem losses in countries like Ghana, Togo, and Benin (Ofori et al., 2023).

The number of people living in Africa's low-lying coastal zones is significant and rapidly increasing, making them highly exposed to environmental hazards intensified by climate change. Africa's sub-Saharan region is identified as part of the most vulnerable regions

globally to a changing climate (Ofori et al., 2021). By 2030, an estimated 108–116 million people are projected to live in regions that are 10 m or less above sea level, with this number potentially doubling by 2060 (Africa Center for Strategic Studies, 2022). Coastal countries like Egypt, Liberia, Madagascar, Mozambique, Nigeria, and Senegal are particularly at risk, with challenges such as flooding caused by storm surges or rising sea levels threatening infrastructure, livelihoods, and public health. Countries where large proportions of the population live on the coast, such as Senegal (41 %), Benin (35 %), and Liberia (29 %), are particularly impacted by sea level rise (Mayson, 2018; Africa Center for Strategic Studies, 2022).

There have been records of infrastructural damage and fatalities caused by such natural disasters. To prevent future natural disasters, coastal defence systems such as groynes, jetties, seawalls, and breakwaters have been built on the coastlines of several African countries (Alves et al., 2020). For example, Ghana, Togo, Benin, Côte d'Ivoire, The Gambia, and Senegal, among others, have built different types of coastal defence systems against future storm surges and tsunamis from impacting their coastal communities and ecosystems (Ndour et al., 2018; Alves et al., 2020). Despite these interventions, rates of coastal erosion within individual countries, especially those with low-lying coastal cities such as Banjul of the Gambia (Jallow et al., 1996) continue to rise (Mather and Stretch, 2012; Alves et al., 2020).

The increasing risks and impacts of climate change led to the adoption of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) as a legally binding treaty on climate change. The agreement was adopted during the 21st Conference of the Parties (COP21) in Paris, France, in December 2015. The goal of the Paris Agreement under Article 2 is “holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change” (UNFCCC, 2015). The Paris Agreement provides a framework for incorporating natural ecosystems as nature-based solutions to enhance countries' climate ambitions.

Since then, countries have been submitting their national climate action plans, known as Nationally Determined Contributions (NDCs). The purpose of each successive NDC is to reflect a degree of ambition that is increasingly higher than the previous version. According to Article 4.9 of the 2015 Paris Agreement, each Party shall communicate a nationally determined contribution every five years following decision 1/CP21 and any relevant decisions of the Conference of the Parties serving as the meeting of the Parties to this Agreement and be informed by the outcomes of the global stocktake referred to in Article 14 (UNFCCC, 2015).

Blue carbon ecosystems, particularly mangrove ecosystems, provide a potentially untapped opportunity to enhance ambition and action in the NDCs of African countries possessing mangroves (Hamilton et al., 2023). In Africa, some countries have frequently prioritised the protection and restoration of terrestrial ecosystems located further inland, such as savannah woodlands and rainforests. However, the significance of mangrove ecosystems in climate change action pledges has been overlooked so far (Gallo et al., 2017; Lecerf et al., 2021).

While the ecological and climate-regulating benefits of mangrove ecosystems are being well documented, there remains a notable gap in the systematic evaluation of the integration of mangroves into national climate strategies. The governance regimes of mangroves have been highlighted as meriting research attention (Dahdouh-Guebas et al., 2022). Specifically, there is no standardized framework for assessing how African coastal countries incorporate mangroves into their NDCs under the Paris Agreement. This lack of a comprehensive evaluation makes it difficult to compare efforts across countries and across regions, or to identify best practices and policy gaps. The present study, therefore, seeks to address this gap by evaluating the extent and quality of mangrove ecosystem integration in the NDCs of African countries. This evaluation will serve as a key component of the set of actions these

countries have developed towards the fulfillment of their climate change adaptation and mitigation commitments as outlined in the Paris Agreement. To accomplish this, we conducted a systematic review of the individual NDCs of all mangrove-possessing countries in Africa that have ratified the Paris Agreement. This study advances knowledge by conducting a systematic and continent-wide evaluation of all the country-specific NDCs to generate a scorecard that highlights the extent to which mangrove ecosystems have been incorporated into the NDCs of each country. While this study presents the level of mangrove integration in the NDCs of selected countries, which is relevant to address the gaps in climate policy, we are aware that the integration of mangrove actions in the NDCs of selected countries does not automatically guarantee the implementation of these actions in any way.

2. Methods

2.1. Study area

Africa has 29,350 km² of mangrove ecosystems, which represent about 20 % of global coverage (Naidoo, 2023). Mangrove ecosystems in Africa thrive in large estuaries and deltas and can be found extending further inland along the banks of rivers influenced by tidal inflows. Moreover, one can also find fringe mangroves lining the shores of some sheltered locations (Naidoo, 2023). Mangrove ecosystems in Africa are located in two major mangrove regions with different mangrove species composition: the Atlantic East Pacific (AEP) and Indo-West Pacific (IWP) mangrove regions (Fig. 1).

2.2. Selection of relevant countries for the study

The selection of relevant countries was based on the criteria that a selected country should.

- i. Be on the African continent or an Island surrounding the African continent,
- ii. Be endowed with a coastline zone that features mangrove ecosystems,
- iii. Have signed the Paris Agreement and provided their NDCs following Article 4.9 of the Paris Agreement.

A total of 33 countries were able to meet all three criteria/conditions and thus found relevant for the study. Among these, 19 countries are located in the Atlantic East Pacific (AEP) mangrove region, and they include Angola, Benin, Cameroon, Côte d'Ivoire, Democratic Republic of Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Guinea-Bissau, Liberia, Mauritania, Nigeria, Republic of Congo, São Tomé and Príncipe, Senegal, Sierra Leone, The Gambia, and Togo. In the Indo-West Pacific (IWP) mangrove region, there are 14 countries present: Comoros, Djibouti, Egypt, Eritrea, Kenya, Madagascar, Mauritius, Mayotte, Mozambique, Seychelles, Somalia, South Africa, Sudan, and Tanzania. Mayotte, which is an overseas department of France, did not have an NDC of its own but was selected on the basis that the European Union (EU), of which France is a member, has signed the Paris Agreement and has provided its NDC. Hence, for the purpose of this study, the NDC of the EU was used for Mayotte.

2.3. Data collection

2.3.1. Document analysis

The primary literature used for this research was the NDCs of the selected countries. We restricted to analysing NDCs as the primary source of data because they represent official, internationally recognized commitments made by countries under the Paris Agreement. As such, they provide a standardized and comparable framework for assessing national-level priorities and strategies. The NDCs were retrieved from the NDC registry of the Paris Agreement (<https://unfccc.int/NDCREG>).

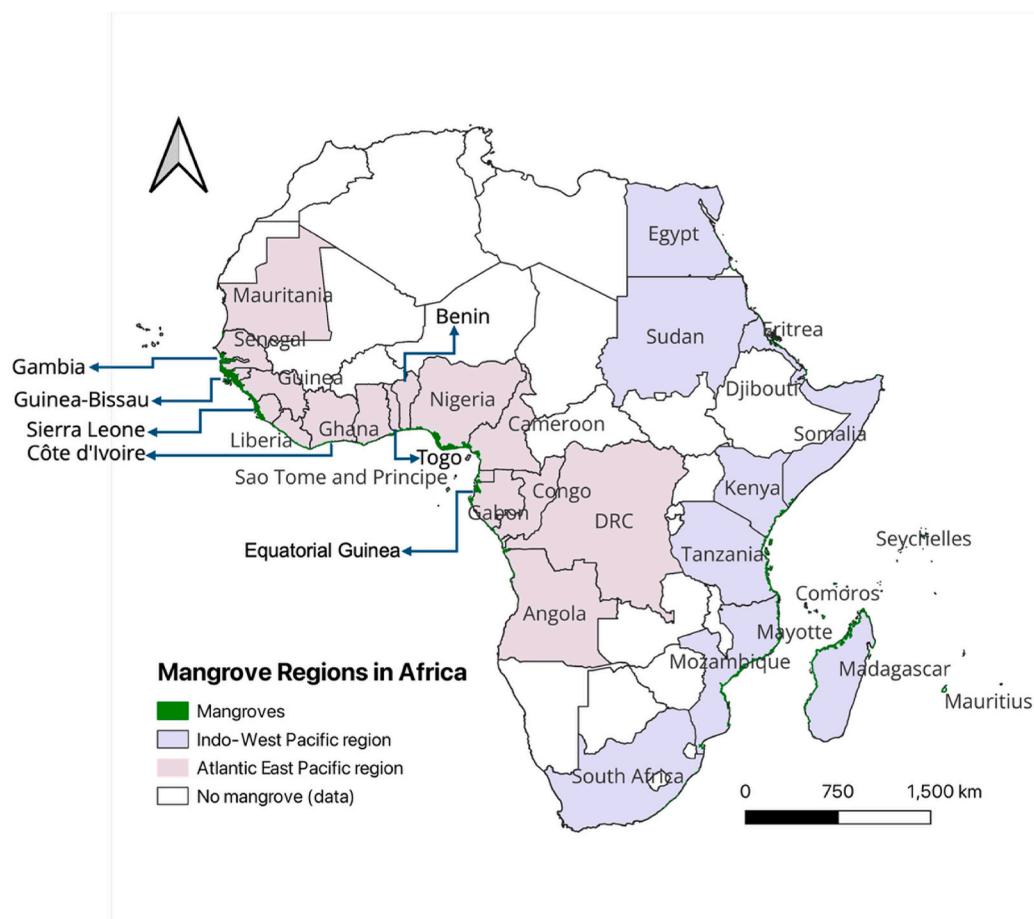


Fig. 1. Map of Africa, showing the two mangrove regions: Atlantic East Pacific (AEP) region and Indo-West Pacific (IWP) region. No mangrove data represents African countries without mangroves. The administrative boundary of Africa was retrieved from [ICPAC Geoportal](#). Mayotte's administrative boundary was accessed from l'Institut national de l'information géographique et forestière (IGN-F) and published in 2022. The 2020 mangrove layer was accessed from [Bunting et al. \(2022\)](#).

A scoping review was conducted for each participating country's NDC using indicators that demonstrate the country's efforts to use mangrove ecosystems in climate change mitigation and adaptation. The summarized version of the indicators used are in the next section, while the detailed version can be found in the supplementary section of this paper.

2.4. Scoring procedure and inter-coder reliability

To enhance the reliability and objectivity of the scoring process, a team of five co-authors conducted the scoring and ranking of the 33 selected countries based on their reviewed NDCs. The team met jointly to assess each country using 11 pre-defined indicators (outlined below), following a structured scoring framework. To minimize the risk of bias and human error, each indicator was discussed collaboratively, and scores were assigned only when full agreement was reached among all five researchers. This approach ensured perfect inter-coder reliability (100 % agreement) across all indicators and countries, thereby strengthening the internal consistency and validity of the assessment. The indicators used for the scoring and ranking of the countries are as follows.

1. Do the NDCs have climate change mitigation strategies?
2. Do the NDCs have climate change adaptation strategies?
3. Do the NDCs have actions for blue carbon or coastal zone/ ecosystem in general?
4. Do the mitigation strategies of the NDCs mention mangrove conservation and restoration?

5. Do the adaptation strategies of the NDCs mention mangrove conservation and restoration?
6. Do the NDCs have a budget for ongoing/future forest or wetland ecosystems?
7. Do the NDCs have a budget for ongoing/future blue carbon or coastal ecosystems?
8. Do the NDCs have a budget for ongoing/future mangrove conservation and restoration?
9. Do the NDCs highlight proposed areas/sites/locations for mangrove conservation and restoration?
10. Do the NDCs mention the timelines of mangrove conservation and restoration?
11. Do the NDCs highlight the surface area or percentage of mangroves to be restored?

The 11 questions were designed to assess how well mangrove ecosystems are included in the NDCs of the selected countries, in relation to climate change adaptation and mitigation. To ensure the scoring framework accurately reflected the study's focus, the authors agreed to assign twice as much weight to mangrove-specific questions (*i.e.*, 4, 5, 8, 9, 10, and 11) compared to general ones. Specifically, each "yes" answer to a mangrove-specific question was scored 2 points while each "yes" answer to a general question was scored 1 point. This approach enabled lower weighting for broader questions that were relevant but not directly tied to mangroves. Furthermore, the authors adopted a similar methodological approach to that used in Lecerf et al. (2021). The remaining questions, which were more general, scored 1 point for a "yes." A country's total score was the sum of its points across all 11

questions. The total integration score for each country was calculated using the following expression:

Total Score (TS) = sum of score points for more general questions (Q_i) + 2 × sum of score points for questions specifically focused on mangroves (Q_j)

$$\text{Thus, } TS = \Sigma Q_i + 2(\Sigma Q_j)$$

Where.

- Q_i represents score point for the i th question – more general, which are: Q1, Q2, Q3, Q6, and Q7)
- Q_j represents score point for the j th question – specifically focused on mangroves, which are: Q4, Q5, Q8, Q9, and Q11, respectively.

Additionally, countries that included budget allocations for mangrove-related actions in their NDCs were automatically given a "yes" for questions 6 and 7, which deal with forests and coastal/blue carbon ecosystems. Similarly, if a country mentioned mangroves in either its mitigation or adaptation strategies, it automatically received a "yes" for question 3, which focuses on blue carbon and coastal ecosystems. These choices were made because mangroves are often classified under various terms such as forests, wetlands, coastal, or blue carbon ecosystems. To make sure we were not missing any detail about mangroves in the NDCs, we checked for any possible terminologies used in place of mangrove ecosystems at the country level.

Based on the scoring system, where each country could score a maximum of 17 points (5 general questions worth 1 point each + 6 mangrove-specific questions worth 2 points each), we categorized the scores into three levels: low, medium, and high integration of mangrove actions into the NDCs. The table below shows the score range for each category and its respective description.

2.5. Data analysis

The absolute scores recorded by countries were used for ranking countries and represented on a tree map using the treemapify package in R version 2024.09.0 + 375. In order to group countries based on their responses (yes or no) to the indicators, the scoring data was transformed into presence-absence data and represented using Non-metric Multidimensional Scaling (NMDS) ordination plots and maps. Maps were created to group countries based on the indicators that were specific to mangrove ecosystems using QGIS version 3.34.0-Prizren (QGIS Development Team, 2024). We used NMDS ordination plots to explore similarity across 33 African countries based on binary responses (1 = "yes", 0 = "no") to the 11 indicators. A Jaccard distance matrix was computed, and NMDS was performed in R using the vegan package (metaMDS, k = 2, 100 runs). The resulting stress value (0.119) indicated a fair fit. Country names were added to the NMDS plot using ggrepel package to improve label clarity. Bar charts were also used to visualize the number of countries that responded "yes" to each of the 11 indicators. All plots, including tree maps, bar charts, and NMDS, used to visualize the scoring data were created using the ggplot2 package in R.

3. Results

3.1. Summary of NDCs of mangrove-possessing countries in Africa

The NDCs of the 33 African countries with mangrove ecosystems were reviewed and summarized in Table 2, focusing on the year of submission, relevant adaptation strategies, mitigation strategies, and budget information provided in the NDCs. This table served as the basis for data collection, enabling the scoring and ranking analysis conducted in this study. The review of the NDCs revealed that out of the 33 countries selected, 23 submitted their documents in 2021. Four countries made their submissions in 2020, three in 2022, and one in 2023.

Table 1

Categorization of countries by level of mangrove integration in NDCs.

| Score Range | Category | Description |
|-------------|------------------------------------|---|
| 0–5 | Low Mangrove Integration | No to minimal inclusion of mangroves; weak or no commitment to mangrove-specific actions in NDCs. |
| 6–11 | Medium Mangrove Integration | Some inclusion of mangrove strategies; limited specificity in targets, budgets, or timelines. |
| 12–17 | High Mangrove Integration | Strong integration of mangroves into both mitigation and adaptation strategies; includes targets, proposed areas, timelines, and budgetary commitments. |

Additionally, three countries—Benin (2019), Eritrea (2018), and Djibouti (2015)—had submissions pre-dating 2020. Additionally, budgetary details were absent in the NDCs of 12 countries. While some countries provided only the overall budget for their NDCs, others delineated the funds required specifically for mitigation and adaptation strategies. A select few went further by itemizing these budgets.

3.2. Countries with mangrove actions indicated in their NDCs

The NDCs of the selected countries were reviewed to determine whether they included actions for mangrove ecosystem conservation or restoration. Among these countries, 17 (i.e., 52 % of the selected countries) included such actions in their NDCs. Six countries (Nigeria, Mauritius, Senegal, Guinea, Somalia, and Sudan) provided mangrove actions in both the adaptation and mitigation strategies of their NDCs (Fig. 2). Seven countries (Benin, Kenya, Togo, Gabon, Mozambique, Djibouti, and Seychelles) mentioned mangrove actions exclusively in their adaptation strategies (Fig. 2). Meanwhile, four countries (Sierra Leone, Liberia, Madagascar, and Equatorial Guinea) included these actions solely in their mitigation strategies.

3.3. Scoring and ranking of NDCs submitted by mangrove-possessing countries in Africa

The level of integration of mangrove ecosystems into the NDCs of the 33 selected countries was assessed using a scoring system based on 11 indicators. Based on these scores, countries are categorized into low, medium, and high classes to demonstrate their level of mangrove action integration into their NDCs (see Table 1). A total of three countries were categorized as high, 11 countries were categorized as medium, and 19 countries were categorized as low. This indicates that 9 % of the 33 countries were categorized as countries with high integration of mangrove actions in their NDCs, while 58 % of the 33 countries were categorized as countries with low integration of mangrove actions in their NDCs. The countries were also ranked to illustrate their commitment to integrating mangrove ecosystems into climate change adaptation and mitigation strategies. Equatorial Guinea and Sudan had the highest level of integration, with 13 out of 17 points (Fig. 3), followed by Senegal with a score of 12 points. Nigeria and Somalia both scored 11 points. Conversely, Mayotte had the lowest level of integration, scoring 1 point (Fig. 3). This categorization and ranking highlight the range of situations regarding how countries address mangrove conservation and restoration within their climate strategies.

The NMDS ordination plot (Fig. 4) illustrates the variation among the 33 assessed countries based on their binary (yes/no) responses to the 11 NDC indicators. The spatial distribution of countries in the NMDS space reflects the diversity in national approaches to mangrove ecosystem integration in their NDCs. Countries clustered on the right side of the plot, such as Nigeria, Sierra Leone, Sudan, Liberia, Somalia, Senegal, Seychelles, and Equatorial Guinea, generally had higher scores, suggesting relatively more comprehensive inclusion of mangroves in their NDCs. Notably, although some countries attained the same scores, their

Table 2

Summary of NDCs of the 33 mangrove-possessing African countries (*NA* represents no available data in a country's NDCs). Mangrove-specific actions of countries are indicated in bold.

| Country (year of submission) | Relevant mitigation measures | Relevant adaptation measures | Budget (Forest/Wetland/Coastal zone/Mangroves) |
|-------------------------------------|---|--|--|
| Angola (2020) | 1. Reforestation of 227,000 ha of forest lands by 2025 with 1015.67 ktCO ₂ e reduction potential 2. Reforestation of 416,000 ha of forest lands by 2025 with 1525.33 ktCO ₂ e reduction potential | As part of Angola's conditional adaptation measures, the country seeks to; 1. Improve the management of existing conservation areas and continue the process of creating new areas by 2025 with a cost of 5.8 million USD. 2. Assess the defence capacity of existing protection structures in risk areas, including the analysis of the feasibility of new investments for the construction of protection structures against sea level rise at a cost of 2 million USD. The unconditional adaptation strategy of the country seeks to; 1. Develop models to analyse the effects of climate change on biodiversity and ecosystems based on national and regional climate change scenarios at a cost of 5.1 million USD 2. Develop actions to preserve forest perimeters in Huambo province, in line with the Government's efforts to elevate the province to the ecological capital of Angola 3. Assess the defence capacity of existing protection structures in risk areas, including the analysis of the feasibility of new investments for the construction of protection structures against sea level rise | 1. A total of 416 million USD for reforestation (conditional) 2. A total of 624 million USD for reforestation (unconditional) |
| Benin (2019) | 1. Promote improved cultural techniques 2. Promote soil fertility 3. Promote hydro-agricultural installations 4. Extend access to electric energy through power generation from natural gases and renewable energy sources 5. Enhance carbon sequestration capacity of forests through sustainable management and restoration 6. Promote agroforestry 7. Promote waste management | 1. Improve the agricultural performance of the country to attain food security 2. Promote integrated water resource management 3. Promote agroforestry 4. Promote mangrove conservation 5. Reduce the vulnerability of coastal environment to sea level rise and ensure continued protection of the coastal zone 6. Promote ecotourism 7. Strengthen health system | 1. A total of 1.48 billion USD for projects related to forests restoration |
| Cameroon (2021) | 1. Promote reforestation, sustainable management and assisted regeneration of forests 2. Adopt renewable energy sources 3. Promote circular economies 4. Promote sustainable agricultural techniques, environmentally friendly and animal and halieutic production | 1. The protection of coastal and inland forests through reafforestation and restoration of the degraded patches. 2. Promote health and gender equality 3. Construct climate-resilient infrastructures 4. Education, sensitization and capacity building regarding climate changes 5. Improve the social life of rural and coastal communities | 1. An amount of 1.05 billion USD for coastal and inland forest protection and restoration |
| Comoros (2021) | 1. Promote renewable energy 2. Promote agroecology and the use of organic fertilizers 3. Improve waste management 4. Promote agroforestry and arboriculture, afforestation and forests restoration | 1. Develop a climate-smart and resilient agriculture 2. Extension of the surface area of protected areas 3. Monitoring and restoration of marine and coastal ecosystems 4. Promote access to improved water 5. Sensitization and capacity building regarding climate change 6. Protect people's health against pandemic, and improve social life of local communities | 1. The NDC presents the overall budget of 1.301 billion EUR 2. The specific budget of mitigation is 902 million EUR 3. The specific budget adaptation is 399 million EUR |
| Côte d'Ivoire (2022) | 1. Improve access to energy 2. Improve agricultural practices and reduce methane emission 3. Improve waste management 4. Combat deforestation, and promote the reforestation of degraded forests | 1. Reduce the vulnerability of the agricultural, livestock and aquaculture sectors 2. Enhance forest governance, reinforce the protection of protected areas and restore degraded forest lands 3. Promote integrated water management 4. Enhance the surveillance of diseases caused by climate change 5. Promote coastal zone management, reinforce coastal surveillance, build the financial and technical capacities of institutions in charge of coastal management and reduce the vulnerability of coastal populations | 1. The overall budget of all initiatives is 22 billion USD 2. The specific budget of mitigation is 10 billion dollars USD 3. The specific budget of adaptation is 12 billion USD |
| Democratic Republic of Congo (2021) | 1. Combat illegal exploitation of forest resources, afforestation of 7 million ha of land and reforestation of 2.5 million ha of degraded forests by 2025 2. Improve agricultural production and livestock in forest areas | 1. Proposed actions include the reforestation of the degraded areas with high economic values, and coastal livelihood diversification. 2. In the coastal zone, the NDC suggests the assessment of the vulnerability of the coastal | 1. A total of 1.3 billion USD for peatlands restoration 2. A total of 5 billion USD for forests conservation, governance, restoration/afforestation, and wetlands conservation |

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Table 2 (continued)

| Country (year of submission) | Relevant mitigation measures | Relevant adaptation measures | Budget (Forest/Wetland/Coastal zone/Mangroves) |
|------------------------------|---|--|--|
| Djibouti (2015) | <ul style="list-style-type: none"> 3. Improve waste management and public transport services 4. Conservation of wetlands, protected areas 5. Conservation, restoration and sustainable use of peatlands as important nature-based solution to combat climate change 1. Djibouti's mitigation strategy focuses on reforestation of agroforestry and silvo-pasture agricultural systems. | <p>ecosystems as well as the need in human and institutional capacities, the fight against erosion.</p> <ul style="list-style-type: none"> 1. Protect and enhance the resilience of the local communities and the ecosystems in the Tadjourah and Hanlé regions through the rehabilitation of ecosystems (plant cover in Hanlé and Tadjourah, and mangroves in the coastal zone of Tadjourah). 2. The rehabilitation of mangroves will enhance their role as a shield for coastal protection against the tides and erosion. 3. In addition, the restoration of coral reefs and mangroves will generate additional | NA |
| Egypt (2022) | <ul style="list-style-type: none"> 1. Emphasizes on enhancing renewable energy capacity, improving energy efficiency, and promoting sustainable practices across various industries. | <ul style="list-style-type: none"> 1. Adaptation of the Northern Delta affected by Sea Level Rise, the natural protection of Rosetta shoreline using the sand motor, and the integration of coastal protection in 3 Egyptian Mediterranean cities | NA |
| Equatorial Guinea (2021) | <ul style="list-style-type: none"> 1. Restore 1300 ha and conserve 24,700 ha of mangroves, resulting in an estimated annual absorption of 344,500 Mg of CO₂ annually 2. Protect 50 % of coasts | <ul style="list-style-type: none"> 1. Restoration of different ecosystems susceptible to losing their resilience | <ul style="list-style-type: none"> 1. Protection of mangrove ecosystems at 5,995,000 USD from 2022 to 2030 and 4,000,000 million USD from 2030 to 2050. |
| Eritrea (2018) | <ul style="list-style-type: none"> 1. Reforestation with agroforestry | <ul style="list-style-type: none"> 1. Development of an afforestation program that will cover over 36,000 ha and the development of terrestrial and marine protected areas of over 1.5 million ha. 2. Promote an Integrated Coastal Marine and Islands Resources Management System by enforcing policy measures and legal frameworks. 3. Avoid all sorts of marine and land-based pollution and regulate fishing activities. 4. Afforestation program will cover over 36,000 ha 5. Desalination of sea water for domestic and economic sectors in 15 coastal towns and villages and 7 islands | <ul style="list-style-type: none"> 1. An amount of 5207.9 million USD for agriculture and forestry |
| Gabon (2020) | <ul style="list-style-type: none"> 1. Combat deforestation, forests degradation, and promote reforestation 2. Replace hydrocarbon energies by renewable energies 3. Promote climate-smart agriculture and urban planning 4. Improve waste management | <ul style="list-style-type: none"> 1. Shift from petrol-dependent economy to a sustainable green economy 2. Reinforce coastal infrastructures at Libreville and Port-Gentil 3. Creation of green space and trees plantation in urban zones to regulate temperature 4. Preservation of strategic ecosystems like mangroves and other coastal forests | NA |
| Ghana (2021) | <ul style="list-style-type: none"> 1. Achieve nature-based solutions for promoting eco-tourism as a means for enhancing biodiversity through forest conservation and landscape restoration. | <ul style="list-style-type: none"> 1. The pursuit of the Green Ghana initiative that incorporates planting seeks to contribute to the maintenance of the vegetation or landscape and to serve as an adaptation measure against the increasing number of extreme weather events in urban areas | <ul style="list-style-type: none"> 1. A total of 392,500,000 USD for gender-responsive sustainable forest management |
| Guinea (2021) | <ul style="list-style-type: none"> 1. Prioritize the sources of renewable energy 2. Modernize the wood-energy 3. Slow down forest degradation through a sustainable forest management, and the increase of the protected areas, including mangroves 4. Improve the effectiveness of the national transport system 5. Place the mining sector on a net-zero emissions trajectory by 2040 6. Improve the collection and the valorisation of urban wastes | <ul style="list-style-type: none"> 1. Elaborate and implement the action plan for the National Policy for Water 2. Elaborate an integrated plan for the coastal zones, and the law on the littoral zone 3. Update the management plan of mangroves and combat the sources of mangrove degradation 4. Put in place strategic measures for efficient coastal zone management | <ul style="list-style-type: none"> 1. The NDC provides an overall budget between 1.94 and 4.37 billion USD 2. A budget of 713 million to 1.922 billion USD for mitigation 3. A budget of 1 billion USD for adaptation |
| Guinea-Bissau (2021) | <ul style="list-style-type: none"> 1. Reduce primary energy demand and promote renewable energy 2. Promote waste management 3. Promote effective conservation of protected areas, ban unnecessary tree cutting, develop national forest restoration programmes and develop agroecology 4. Promote sustainable agricultural practices and improve crop production | <ul style="list-style-type: none"> 1. Domains that are considered in NDC for the adaptation segment included food security, water resources, coastal zones, and forests. No details provided about actions in these domains | <ul style="list-style-type: none"> 1. A total of 264 million USD for the forest and land use segment under mitigation strategies |

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Table 2 (continued)

| Country (year of submission) | Relevant mitigation measures | Relevant adaptation measures | Budget (Forest/Wetland/Coastal zone/Mangroves) |
|------------------------------|---|---|--|
| Kenya (2020) | <ol style="list-style-type: none"> 1. Harness the mitigation benefits of the sustainable blue economy, including Payment for Ecosystem Services (PES) programmes for coastal carbon 2. Scaling up Nature-based Solutions (NbS) for mitigation | <ol style="list-style-type: none"> 1. Strengthening socio-economic aspects for blue carbon governance, 2. Promote and expand opportunities for nature-based enterprises, including seaweed farming and mangrove ecotourism, 3. Integrate the use of nature-based solutions, including implementation of the national mangrove ecosystem management plan (NMEMP), into national and county development plans | <ol style="list-style-type: none"> 1. Enhance sustainable 587 million USD for blue economy and fisheries development 2. A total of 78 million USD to reduce emissions from deforestation and forest degradation |
| Liberia (2021) | <ol style="list-style-type: none"> 1. Improve protection and conservation measures in 30 % of mangrove ecosystems and reduce GHG emissions by a total of 1800 GgCO₂e through avoided conversion and draining of mangrove ecosystems by 2030 2. Enhance coastal carbon stocks by restoring 35 % of degraded coastal wetlands and mangrove ecosystems by 2030 (Link to Fisheries sector) | <ol style="list-style-type: none"> 1. Design and implement green-gray infrastructure approaches along 60 % of Liberia's highly vulnerable coastline by 2030 (Link to Transport sector) 2. Establish an early warning system and predictive scenario modelling for climate disasters and coastal flooding by 2030. | <ol style="list-style-type: none"> 1. A total of 32,200,000 USD for mitigation under the coastal zone sector 2. A total of 22,650,000 USD for adaptation under the coastal zone sector to design and develop green-gray infrastructure approaches in Liberia's highly vulnerable coastline |
| Madagascar (2022) | <ol style="list-style-type: none"> 1. Build the capacity of institutions and stakeholders to fight climate change 2. Promote smart and biological agriculture 3. Promote REDD + initiatives and sensitize stakeholders for conservation activities 4. Regulate urban transport and promote renewable energies 5. Promote innovative processes for waste management 6. Restoration of mangroves | <ol style="list-style-type: none"> 1. Promote research on climate-health, and agrobiodiversity 2. Operationalize the integrated water resources management 3. Promote forest and biodiversity conservation 4. Promote integrated coastal zones management, combat coastal degradation and coastal erosion 5. Enhance the protection of marine protected areas (MPAs) | <ol style="list-style-type: none"> 1. A total of 11.62 billion USD for adaptation and 7.29 billion USD for mitigation |
| Mauritania (2021) | <ol style="list-style-type: none"> 1. Assisted natural regeneration of forests 2. Restoration and conservation of sites of ecological and biological interest | <ol style="list-style-type: none"> 1. Protection and conservation of ecosystems including wetlands, sustainable rangeland management, biodiversity conservation, fisheries and aquaculture, habitat and urban planning. | <ol style="list-style-type: none"> 1. A total amount of 10.63 billion USD is budgeted for adaptation strategies 2. A total amount of 34.3 billion USD is budgeted for mitigation strategies |
| Mauritius (2021) | <ol style="list-style-type: none"> 1. Assessment and monitoring of blue carbon in coastal and marine ecosystems (mangroves, tidal marshes and seagrasses) 2. Develop a comprehensive ecosystem-management 3. Create joint efforts (with local communities, NGOs) to restore ecosystems and, thus, the carbon storage capacity (mangrove, forest, coral reef rehabilitation) | <ol style="list-style-type: none"> 1. Improve management of marine and terrestrial protected areas and expansion of protected area network including rehabilitation of wetlands, seagrass, mangrove plantation, increase in tree coverage areas and coral reef rehabilitation/farming. | NA |
| Mayotte (2023) | <ol style="list-style-type: none"> 1. The EU's NDC mentions wetlands in the Land-Use Land Cover categories to report on emissions and removals | NA | NA |
| Mozambique (2021) | <ol style="list-style-type: none"> 1. Focuses on the application and expansion of agricultural production techniques of a conservationist and soil protection nature, such as the use of direct planting | <ol style="list-style-type: none"> 1. Increase the resilience of fisheries by regenerating mangroves and implementing protective measures for seaweed and seagrass, corals, and other breeding and feeding areas for fish. | NA |
| Nigeria (2021) | <ol style="list-style-type: none"> 1. Protection and restoration of mangrove forest ecosystems (13,012 ha of mangrove ecosystems across all the coastal states in the Niger Delta)" | <ol style="list-style-type: none"> 1. Mangrove restoration and management, which act as a buffer for coastal communities. 2. Protect and restore degraded watersheds and wetlands to protect water resources and related ecosystems services. | NA |
| Republic of Congo (2021) | <ol style="list-style-type: none"> 1. Proposed actions for energy, agriculture, forests and other land use systems, industrial processes and product utilization and waste management. 2. In the forestry sector, the NDCs put forward actions like reforestation and assisted regeneration of forests | <ol style="list-style-type: none"> 1. Promotion of a resilient food security, the reinforcement of the resilience of people's livelihood, and strengthening the climatic information systems for a resilient development in Congo. 2. Promote coastal resilience and strengthen the capacity of institutions and communities who manage the coastal area. 3. Priority areas to manage coastal flooding and sea-level rise include mangrove plantations, coastal defence structures, coastal rehabilitation and relocation/resettlement, and climate risk and vulnerability assessments in provinces | <ol style="list-style-type: none"> 1. For adaptation strategies, an amount of 39 million USD is budgeted for projects in the coastal zone areas 2. For mitigation strategies, an amount of 8 million USD is budgeted for projects in forests restoration |
| São Tomé and Príncipe (2021) | <ol style="list-style-type: none"> 1. The country's mitigation measures do not include the land-use, land-use change, and forestry (LULUCF) sector given the country's | <ol style="list-style-type: none"> 1. Strengthening of resilience and adaptation of coastal communities, and the strengthening of marine security for artisanal fishers | NA |

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Table 2 (continued)

| Country (year of submission) | Relevant mitigation measures | Relevant adaptation measures | Budget (Forest/Wetland/Coastal zone/Mangroves) |
|------------------------------|--|--|---|
| Senegal (2020) | <p>climate neutrality estimated in initial GHG emissions inventory calculations.</p> <p>1. Restoration of 1297 ha of mangroves per year in the unconditional NDC</p> <p>2. Restoration of 4000 ha of mangroves per year in the conditional NDC.</p> | <p>1. Promote integrated coastal zone management</p> <p>2. Restore and sustainably manage mangroves</p> <p>3. Improve the conservation and protection of marine protected areas (MPAs)</p> <p>Promote the integrated management of water resources</p> <p>1. Focuses on coastal management, critical infrastructure, fisheries, tourism, agriculture and biosecurity, resilience of blue carbon ecosystems, biodiversity and conservation, health as well as early warning and disaster risk management.</p> <p>2. In the coastal management section, actions proposed by the NDC captured mangroves, and aimed at prioritizing nature-based solutions to protect coastal ecosystems from climate actions.</p> <p>3. Put in place mechanisms to effectively protect at least 50 % of Seychelles seagrass and mangrove ecosystems by 2025, and 100 % of seagrass and mangrove ecosystems by 2030</p> <p>1. Manage coastal and fisheries resources by promoting sustainable utilization of coastal and fisheries resources through legislative reforms and enforcement to enhance economic growth</p> | <p>1. For mitigation strategies, an amount of 454,798,100 USD is budgeted for the forestry sector</p> <p>2. For adaptation strategies, an amount of 663,569,800 USD is budgeted for the intergraded coastal zone management sector</p> <p>1. Monitoring of blue economy strategy: 7.04 million USD</p> <p>2. Coastal management and tourism: 89 million USD</p> |
| Seychelles (2021) | 1. Actions cut across several sectors, including energy, transport, solid waste management as well as responsible tourism and circular economy | | |
| Sierra Leone (2021) | <p>1. Develop a blue carbon initiative for the Sierra Leone River and Bonthe-Sherbro River Estuaries to conserve vast mangrove and seagrass resources while sequestering tree and soil organic carbon</p> <p>2. Develop REDD + initiative for the Mangrove reserve in the Sierra River Estuary</p> <p>3. Restore, enhance, and manage about 5000 ha of its vastly degraded mangrove resources over the next 10 years</p> <p>4. Support the scaling of Marine Protected Areas (MPAs) and energy-efficient deployments in fishing boats, coastal recreational facilities, and fish landing sites</p> | <p>1. Manage coastal and fisheries resources by promoting sustainable utilization of coastal and fisheries resources through legislative reforms and enforcement to enhance economic growth</p> | <p>1. A total of 30,000,000 USD for maintaining the integrity of the marine and coastal environment</p> |
| Somalia (2021) | 1. Afforestation and reforestation of degraded forests, including mangroves in order to reduce 18.10 MtCO₂eq by 2030 | <p>1. As part of the measures proposed under the coastal, marine environment and fisheries sectors, a mangrove and shoreline restoration program.</p> | <p>1. An amount of 3.850 billion USD was budgeted for afforestation and reforestation of degraded forests including mangroves restoration.</p> <p>2. An amount of 3 billion USD for coastal and marine activities, which include a mangrove and shoreline restoration program</p> |
| South Africa (2021) | 1. Achieve annual GHG emissions in a range from 398 to 510 Mt CO ₂ -eq in 2025 and annual GHG emissions of 350–420 MgCO ₂ -eq by 2030 through Energy, IPPU, AFOLU, and Waste | <p>1. Enhance the monitoring of climate change impacts on biodiversity and ecological infrastructure</p> | NA |
| Sudan (2021) | <p>1. Restoration and sustainable management of degraded forest reserve and Gum Arabic belt.</p> <p>2. Afforestation and restoration of degraded lands in 10 % of rainfed areas and 5 % of irrigated agriculture scheme areas.</p> <p>3. Restoration/conservation of mangrove forests in Red Sea State.</p> <p>4. Implementation of the National REDD + Strategy in Blue Nile, Gadarif and Sinnar States.</p> | <p>1. Mangrove restoration and management for building resilience of dependent local communities especially in marine subsistence and commercial fisheries and through addressing multiple stresses using approaches based on science and participation.</p> <p>2. Provision of alternative livelihoods for mangrove-dependent communities.</p> <p>3. Integration of adaptation options into coastal zone management planning.</p> <p>4. Strengthening coastal communities to use Ecosystem Based Management approaches to improve fisheries management and achieve other marine resource benefits.</p> <p>5. Protection of coral reef and, sea grass beds and restoration of degraded areas and areas especially sensitive to climate related risks.</p> <p>6. Increased resilience of islands against climate impacts.</p> <p>7. Mapping, demarcation of coastal hazard lines subjected to sea level rise and over flooding.</p> <p>1. Enhancing participatory sustainable forest and wildlife management and protection</p> | <p>1. A total of 120 million USD for the forestry sector under the mitigation strategy</p> <p>2. A total of 37 million USD for implementation of the National REDD + Strategy in Blue Nile, Gadarif and Sinnar States under the mitigation strategy</p> <p>3. A total of 150 million USD for building resilience in coastal zones under the adaptation strategy</p> |
| Tanzania (2021) | 1. Enhancing and upscaling implementation of participatory forest management programmes. | | NA |

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Table 2 (continued)

| Country (year of submission) | Relevant mitigation measures | Relevant adaptation measures | Budget (Forest/Wetland/Coastal zone/Mangroves) |
|------------------------------|--|---|---|
| The Gambia (2021) | 2. Facilitating effective and coordinated implementation of actions that will enhance the contribution from the entire forest sector 3. Promote nationwide forest landscape restoration programmes and initiatives. | 2. Safeguarding ecosystem services, including through the promotion of alternative livelihood options to forest dependent communities 3. Strengthening forestry research and development to promote resilience to climate stress 4. Strengthening management of coastal and marine resources and monitoring systems. 5. Promoting sustainable livelihood diversification for coastal communities 6. Improving early warning systems of both sea level rise impacts and extreme weather events 7. Increasing productivity in an environmentally sustainable way through inter alia climate-smart fisheries and aquaculture interventions 8. Enhancing area-based management systems for a sustainable blue economy | 1. An amount of 13,000,000 USD for coastal ecosystem management |
| Togo (2021) | 1. Re-greening degraded landscapes (including protected forests) through Planting and management (afforestation) and fire prevention and control 2. Promote sustainable agricultural practices 3. Enhance waste management 4. Regulate GHG emissions from industries 4. Improve road infrastructures and promote green mobility 5. Promote forest restoration, improve land management, develop urban forestry and promote timber and non-timber forest products and their value chains | 1. Highlights three technological needs of the coastal resources which include sustainable sand management, breakwater systems, and groyne systems 2. Support the planning, rehabilitation and management of buffering coastal ecosystems to build the resilience of fisheries and tourism development 1. Promote an integrated and sustainable water resource management 2. Enhance the efficiency of the energy sector and promote the use of renewable energies 3. Put in place an early warning system to combat flooding, fight against tropical diseases and reinforce social protection 4. Reinforce the socioeconomic resilience of the coastal zone, combat coastal erosion, and rehabilitate mangrove ecosystems 5. Reinforce the resilience of the agricultural production systems, promote the sustainable use of forests ecosystems and restore ecosystem services | 1. A total of 1.03611 billion USD for the forests and other land uses of the mitigation section 2. A total of 180.38 million USD for forests and other land uses of the adaptation section 3. A total of 249.50 million USD for the coastal zones management in the adaptation action |

positions remain distinct. For example, both Nigeria and Somalia scored 11 points, while Equatorial Guinea and Sudan scored 13, and Sierra Leone and Seychelles scored 10 points; yet each pair occupies separate positions in the ordination space, indicating differences in response patterns despite equal total scores.

In the central region of the plot, some countries with identical scores exhibited spatial proximity, while others did not. For instance, although Togo, Kenya, Djibouti, Guinea, and Mauritius all scored 7 points, Togo and Kenya appeared close to each other, as did Guinea and Mauritius, while Djibouti was relatively distant from both groups. A tight cluster of countries such as Guinea-Bissau, Eritrea, Angola, DRC, and Cameroon, all scoring 4 points, suggests a high degree of similarity in how these countries address mangrove integration in their NDCs. A similar pattern is observed among São Tomé & Príncipe, Comoros, Tanzania, Egypt, and Côte d'Ivoire, all of which scored 3 points.

The distinctly isolated positioning of Mayotte in the NMDS space reflects its strong dissimilarity from the other countries in terms of mangrove ecosystem integration within its NDCs.

The analysis of the number of countries responding positively to each indicator was used to evaluate the integration of mangrove ecosystems into their NDCs. Fig. 5 shows the number of indicators that were mangrove-specific (in sky-blue) and those that were not (in orange). It indicates that all 33 countries included relevant climate change mitigation and adaptation strategies in their NDCs, except Mayotte, which did not include an adaptation strategy in its NDCs. Out of the 33 countries whose NDCs were reviewed, only 10 and 13 included mangroves specifically in their mitigation and adaptation strategies, respectively. Moreover, only two of these countries, which included

mangroves in their adaptation and mitigation strategies, had budgets specifically allocated for these mangrove actions in their NDCs. Additionally, only three countries mentioned specific proposed areas designated for mangrove actions in their NDCs.

3.4. Budgetary commitments for mangrove actions

The NDCs of all 33 mangrove-possessing countries were also evaluated to determine if budgets were allocated for mangrove actions, as a measure of their integration of mangrove ecosystems into climate change mitigation and adaptation strategies. Some countries divided their budgets into two categories: one for adaptation and the other for mitigation. It was identified that 14 countries prepared budgets for forests or wetlands, and 11 countries allocated budgets for blue carbon or coastal ecosystems. However, only two countries, Equatorial Guinea and Somalia, had budgets explicitly prepared for mangrove actions in their NDCs (Fig. 6). Equatorial Guinea allocated USD 5.995 million for mangrove ecosystem protection from 2022 to 2030, and USD 4 million for the period between 2030 and 2050. Somalia allocated a budget of USD 3.850 billion with a target year of 2030 for afforestation and reforestation activities, including mangrove restoration, as part of broader forest rehabilitation efforts.

3.5. Designated mangrove action areas

The review of the NDCs of the selected countries assessed whether proposed areas for mangrove actions were specified. Among these, four countries, i.e., Nigeria, Djibouti, Sierra Leone, and Sudan, indicated

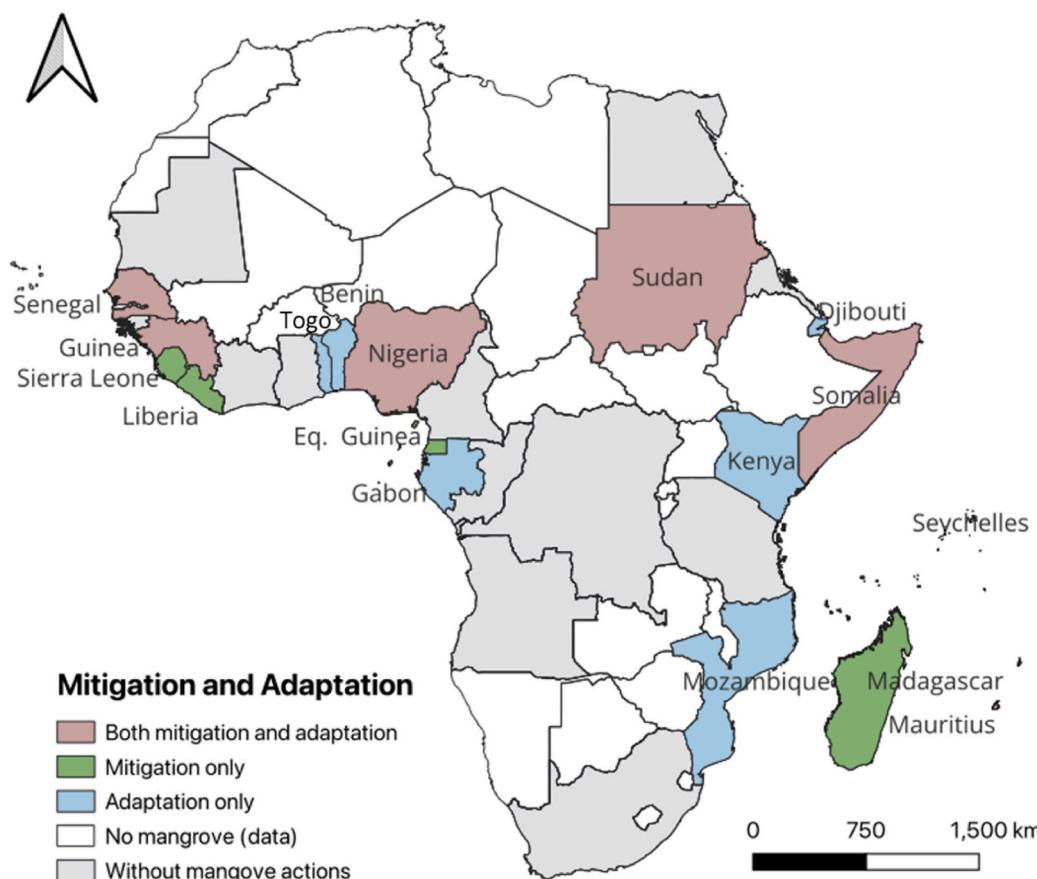


Fig. 2. A map showing the countries that included mangrove actions in their NDCs' adaptation and/or mitigation strategies. Green represents countries with mangroves in their mitigation strategies, blue represents countries with mangroves in their adaptation strategies, and pink represents countries with mangroves in both adaptation and mitigation strategies.

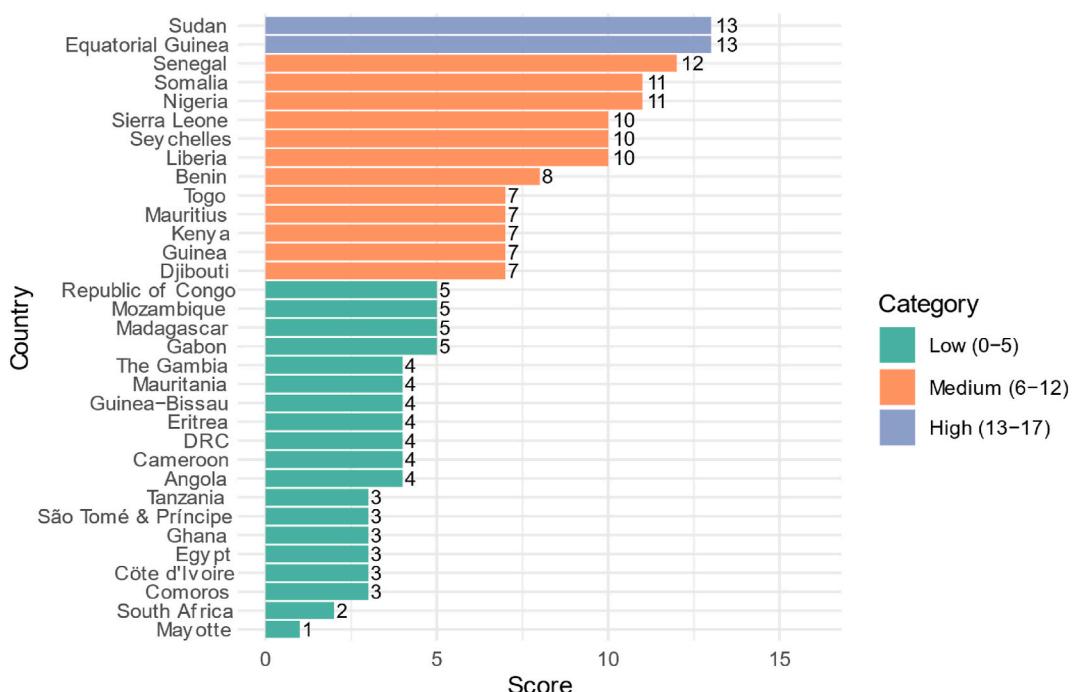


Fig. 3. Levels of mangrove action integration in NDCs across the 33 mangrove-possessing African countries. The bar chart visualizes the total score of each of the 33 countries based on 11 indicators assessing the inclusion of mangrove ecosystems in their NDCs. Countries are categorized into Low (0–5), Medium (6–12), and High (12–17) levels of integration.

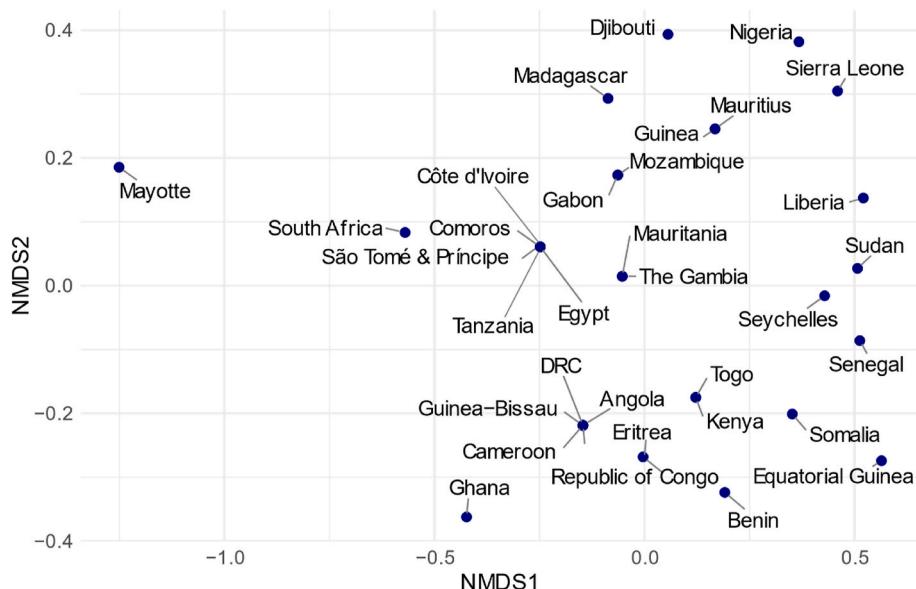


Fig. 4. Non-metric Multi-Dimensional Scaling (NMDS) plot showing similarities between the 33 countries (green circles) based on their relative scores to the 11 indicators demonstrating the level of mangrove integration in their NDCs (Jaccard measure of association; stress = 0.119).

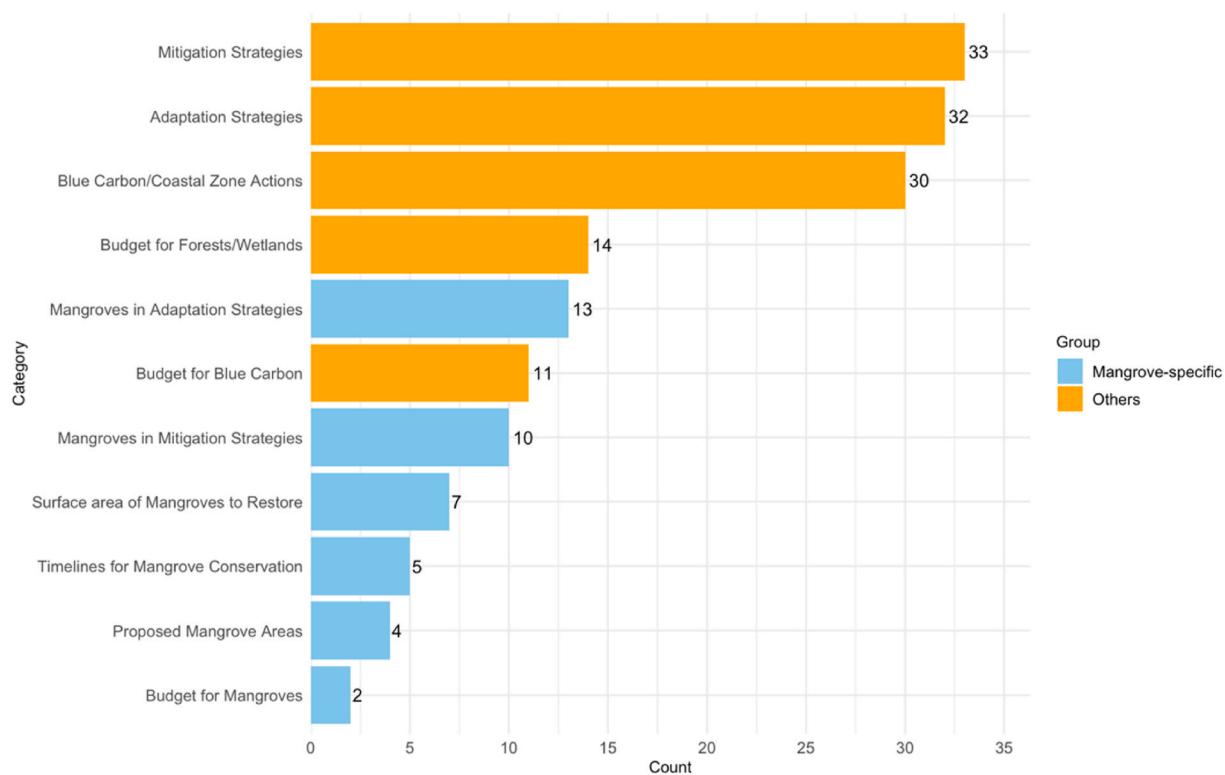


Fig. 5. Bar chart showing the number of countries whose NDCs presented information on each of the 11 indicators. Indicators are grouped into two groups, i.e., "mangrove-specific" in blue-coloured bars and "others" in orange-coloured bars.

locations or areas for conserving or restoring mangroves (Fig. 6). Djibouti proposed protecting and enhancing the resilience of both local communities and mangroves in the Tadjourah coastal zone. Nigeria aimed to protect and restore 13,012 ha of mangrove ecosystems across coastal states in the Niger Delta. Sierra Leone planned a blue carbon initiative targeting the Sierra Leone River and Bonthe-Sherbro River Estuaries to conserve extensive mangrove and seagrass ecosystems while enhancing carbon sequestration. Sudan has indicated plans to restore or conserve mangrove forests in the Red Sea State.

3.6. Targeted mangrove restoration goals

The review also investigated whether countries specified the number of hectares or percentage of mangroves to conserve or restore in their NDCs, as these details signify a higher level of integration of mangrove ecosystems in climate strategies. Out of the 33 countries, seven (Equatorial Guinea, Liberia, Nigeria, Senegal, Seychelles, Sierra Leone, and Sudan) provided such quantitative details (Fig. 6). These countries included conservation or restoration targets expressed in hectares or

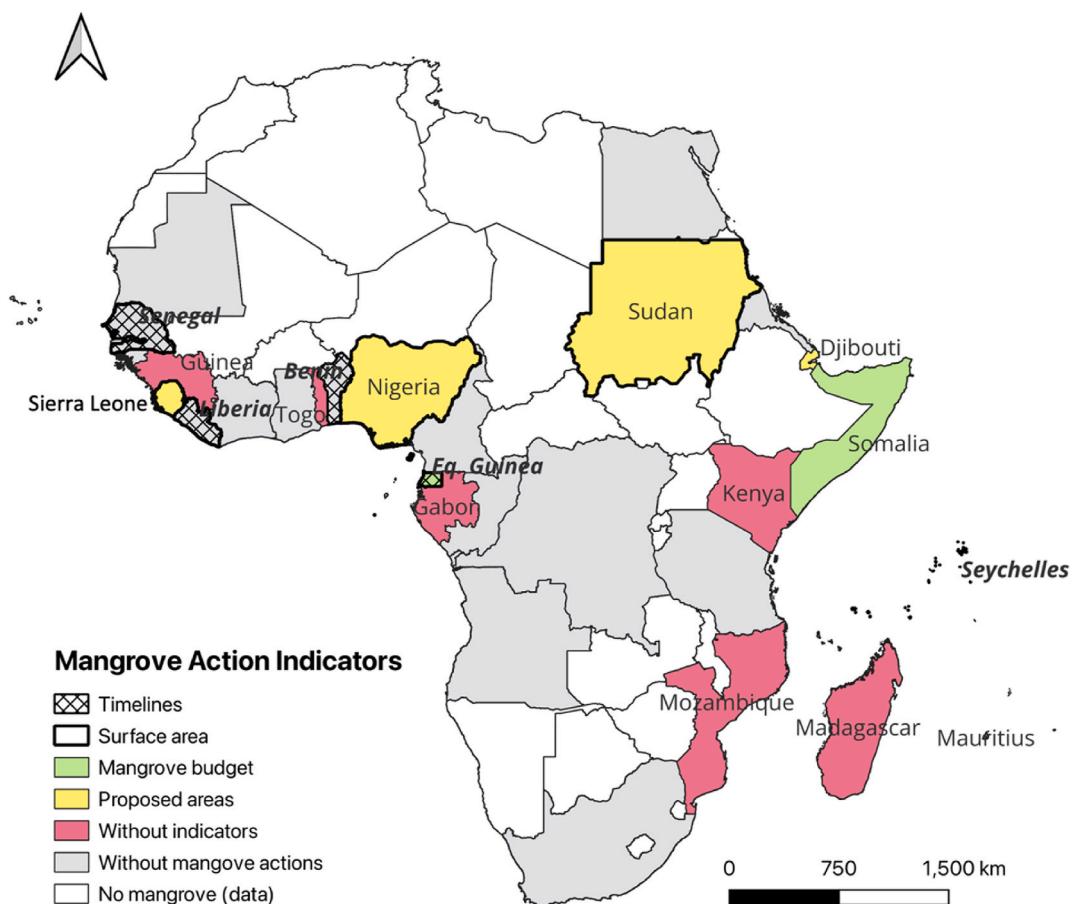


Fig. 6. Map showing countries having NDCs with: budgets allocated for mangrove actions (green: Somalia and Equatorial Guinea), proposed areas for mangrove restoration and conservation (yellow: Sierra Leone, Nigeria, Djibouti and Sudan), timelines for achieving mangrove actions (hatched and labelled in bold italic: Senegal, Liberia, Benin, Equatorial Guinea, and Seychelles), and surface area allocated for mangrove actions (thicker country borders: Senegal, Liberia, Sierra Leone, Nigeria, Sudan and Seychelles). Countries with mangrove actions but no indicators are coloured in pink (Mauritius, Guinea, Madagascar, Kenya, Togo, Gabon, and Mozambique).

percentages, reflecting a measurable commitment to addressing mangrove ecosystem challenges.

3.7. Timelines for mangrove action

The NDCs were further analysed to determine which countries included timelines for achieving mangrove actions, indicating their commitment to integrating these ecosystems into climate strategies. Among the 16 countries that included mangrove actions in their NDCs, five (Senegal, Liberia, Benin, Equatorial Guinea, and Seychelles) specified timelines for these actions (Fig. 6). Liberia and Benin set targets for 2030, Seychelles identified milestones for 2025 and 2030, and Equatorial Guinea indicated 2050 as the year for achieving its mangrove-related targets.

4. Discussion

Mangrove ecosystems have gained international attention, mostly due to their crucial role as nature-based solutions in climate change mitigation and adaptation (Hamilton et al., 2023). The socio-ecological and climate benefits of mangroves have led to an increasing call made by international organizations to countries possessing mangroves to take advantage of these ecosystems by including them in their NDCs towards climate change mitigation and adaptation (Fobissie et al., 2019; Hamilton et al., 2023; Hehmeyer et al., 2019).

As we investigated the inclusion of mangroves in the NDCs of the 33 African countries possessing mangroves, we found out that only six

(Guinea, Mauritius, Nigeria, Senegal, Somalia, and Sudan), which represents 18 % of the total countries, presented actions for mangrove ecosystem in both the adaptation and mitigation strategies of their NDCs. A bibliometric analysis conducted by Ho and Mukul (2021) showed Africa's underrepresentation during a rising trend in mangrove-related studies globally. This reveals a lack of capacity or interest exhibited by African countries possessing mangroves.

Among a list of countries with a high number of mangrove-related studies, South Africa ranked 22nd and was the top productive country in Africa with 174 articles amidst its relatively smaller mangrove extent of 26.43 km² (Ho and Mukul, 2021; Bunting et al., 2022; Naidoo, 2023). However, even as the top mangrove research-producing country in Africa, South Africa did not include mangrove actions in both mitigation and adaptation strategies of its NDCs, ranking 32nd out of the 33 selected countries. This points to a disconnect between research outputs and policy frameworks and potentially reveals a lack of collaboration existing between governments, NGOs, ministries, agencies, departments, and research institutions working in these countries when it comes to the development of policies and national frameworks, for mangrove conservation and restoration. Hamilton et al. (2023) recommended the need for cross-sectoral engagement where there is consultation and collaboration between governments, stakeholders, and experts from relevant sectors working together in developing these NDCs. These collaborations will lead to developing NDCs that present evidence-based mangrove actions relevant at the country level with empirical information on their socio-ecological and climate action benefits.

Working in isolation often results in developing NDCs that are unable to effectively make use of nature-based solutions like mangrove ecosystems in tackling the climate crisis. The lower number of countries including actions for mangrove ecosystems in both the adaptation and mitigation strategies of their NDCs reveals a limited understanding of countries on the socio-ecological benefits of mangroves when compared to other terrestrial ecosystems (Fobissie et al., 2019; Röser et al., 2020). With the majority of the NDCs not presenting specific mangrove actions, it can be deduced that some of these countries due to the limited awareness of the significant carbon sequestration potential of mangrove ecosystems may have their focus on reducing emissions through deforestation reduction and conservation of terrestrial forests.

Moreover, four countries (Sierra Leone, Liberia, Madagascar, and Equatorial Guinea) included mangrove actions only in their mitigation strategies, while seven countries (Benin, Kenya, Togo, Gabon, Mozambique, Djibouti, and Seychelles) included mangrove actions only in their adaptation strategies. Countries that exclusively include mangroves in their NDC mitigation strategies likely prioritize their carbon sequestration potential, while countries that exclusively include mangroves in their NDC adaptation strategies may view the value of mangroves in enhancing coastal resilience, protecting against storm surges, and supporting livelihoods dependent on fisheries. This reaffirms the potential knowledge or resource gaps (Röser et al., 2020) where countries may not fully appreciate or have the capacity to implement mangrove conservation for both mitigation and adaptation. As presented by Fobissie et al. (2019), the issue of financial, institutional, and technological barriers faced by countries in implementing their NDCs may have resulted in the low level of effective inclusion of mangrove actions in the NDCs of the selected countries.

The Sub-Saharan African region is identified as one of the most vulnerable regions in the world to the changing climate due to its very low technical and financial capacity to adapt to or mitigate climate change (Ofori et al., 2021). We found that the majority of the selected countries that occur in the most vulnerable region are greatly missing out on taking advantage of these mangrove ecosystems in reducing their climate change risks while contributing to the efforts to limit global warming to 1.5 °C above pre-industrial levels, as outlined in the Paris Agreement (UNFCCC, 2015). Countries yet to integrate mangrove actions into both the adaptation and mitigation strategies of their NDCs are encouraged to draw lessons from pioneers like Guinea, Mauritius, Nigeria, Senegal, Somalia, and Sudan, which have taken significant steps in this direction. This analysis, therefore, presents opportunities for the sharing of knowledge and innovative technologies among countries towards the effective inclusion of mangrove actions in their NDCs and their successful implementation (Röser et al., 2020).

The scoring analysis highlights a significant variation in how African countries with mangrove ecosystems integrate these critical ecosystems into their NDCs. Having only 9% (i.e., Equatorial Guinea, Senegal, and Sudan) of the 33 countries falling within the high mangrove integration category underscores that 91% of the mangrove-possessing countries in Africa have medium to low interest in using mangrove ecosystems as nature-based solutions to the changing climate. This unprecedentedly low integration of mangrove actions in the NDCs of these countries, as revealed in this study, is one of the critical issues requiring immediate attention from the country governments, NGOs, and the scientific community. From a total score standpoint, Equatorial Guinea and Sudan lead with the highest score (13 points), reflecting the relatively stronger and more comprehensive commitment of these countries to utilizing mangrove ecosystems as a nature-based solution for climate action. However, it is important to note that recording the highest score to be 13 points demonstrates that there is still room for these countries to improve upon their inclusion of mangrove actions in their NDCs.

Equatorial Guinea's climate efforts are particularly notable in the protection of mangrove ecosystems. The country has set ambitious targets for mangrove conservation and restoration. By 2050, it aims to restore 1300 ha and conserve 24,700 ha of mangroves, resulting in an

estimated annual absorption of 344,500 tons of CO₂. Additionally, by 2030, Equatorial Guinea plans to integrate the principles of the blue and green economy into relevant legal frameworks and implement at least one project in these sectors. The goal for 2050 is to protect 50% of the nation's coastal areas. Although Equatorial Guinea scored the highest alongside Sudan, it is important to note that it is one of the countries that exclusively included mangroves in their NDC mitigation strategies, prioritizing the carbon sequestration potential of their mangrove ecosystems. This indicates that there is more room for Equatorial Guinea to improve its NDCs by including mangrove actions into its adaptation strategies.

Sudan is known to be a country with a considerably small area of mangroves for a country of its size. However, amidst its small mangrove area, Sudan is among the few countries with its mangroves protected under various legal frameworks, including forestry, environmental protection, and public health laws. Key acts include the Central Forestry and Provincial Forestry Acts of 1932, the Public Health Act of 1973, the Forests Act of 1989, and the Forests National Corporation Act of 1986 (Sabeel, 2015). Additional protection is provided by the Environment Protection Act of 2000, the Environmental Protection Act of 2001, and the Forests and Renewable Natural Resources Act of 2002 (Sabeel, 2015). It is, however, important to note that there may be large gaps between theoretical and real-life protection of mangroves, especially in a war-torn country like Sudan. While these two countries scored the highest among the 33 countries, mangrove research in Equatorial Guinea and Sudan however, remains limited, as an online search through databases such as Google Scholar and Web of Science revealed very few studies focused on either country's mangrove ecosystems. This highlights a significant need for increased research efforts to fully explore and leverage the ecological and economic potential of these vital ecosystems.

Senegal, with a score of 12 points, closely follows Equatorial Guinea, reflecting proactive efforts to integrate mangroves into its NDCs. Senegal is one of the six countries that presented actions for their mangroves in both the adaptation and mitigation strategies of their NDCs. Senegal's track record in wetland restoration and community-based mangrove restoration aligns with its relatively high score, showcasing its understanding of mangroves' role in supporting livelihoods and mitigating coastal erosion. Several mangrove restoration initiatives have been developed in Senegal, which may suggest political will towards nature-based solutions and access to global carbon markets. Existing collaborations between research institutions, government bodies like Senegal's Ministry of Environment, and NGOs have contributed to the country's strong commitment to mangrove conservation and restoration, and their inclusion in its NDCs. To ensure the long-term success of these restoration efforts, best practices that include active involvement of local communities, use of native species, restoration of natural hydrology, planting in appropriate sites, and continuous monitoring and adaptive management should be employed (Zimmer et al., 2022). Lessons can also be learnt from other countries like Sri Lanka, where inefficient communication, inconsistencies between policies, and insufficient financial capacity of government stakeholders responsible for policy implementation hampered effective mangrove management (Nijamdeen et al., 2023).

Nigeria and Somalia, each scoring 11 points, reflect a moderate level of integration of mangrove ecosystems into their Nationally Determined Contributions (NDCs). In Nigeria, this score underscores the country's acknowledgment of the ecological and socio-economic importance of mangroves, particularly as they face significant threats from industrial activities such as oil exploration, coastal development, and deforestation (Sam et al., 2023). Nigeria's inclusion of mangroves in its NDCs indicates a growing commitment to leveraging these ecosystems for both mitigation and adaptation purposes, recognizing their carbon sequestration potential and their role in coastal protection.

For Somalia, the score reflects efforts to address the country's acute climate vulnerabilities, particularly within its fragile coastal zones.

Somalia's mangroves play a critical role in shielding coastal communities from rising sea levels and storm surges while supporting livelihoods through fisheries and other ecosystem services. However, the country's fragile governance and limited resources (World Bank, 2024) likely pose challenges to comprehensive mangrove management, which is reflected in its moderate score. Both countries highlight the complex interplay of environmental challenges and opportunities in integrating mangroves into broader climate action frameworks.

At the lower end of the spectrum, Mayotte's score of 1 point reveals minimal integration of mangrove ecosystems in the climate strategies of the EU since Mayotte is a territory of France. This may be attributed to inadequate policy prioritization of mangrove ecosystems in the EU and the fact that the EU's NDCs focus on its mainland (and its ecosystems) and do not consider its overseas territories (Ferdinand, 2018). The disparities in scores reflect regional and national differences in capacity, resource availability, and prioritization of mangrove conservation or restoration. Countries with higher scores tend to have larger mangrove extents and effective institutional frameworks for addressing climate challenges. Conversely, lower-scoring countries may lack the necessary resources or technical expertise to integrate mangroves into their NDCs effectively.

In reviewing the NDCs, we observed a striking disparity in financial commitments of the 33 countries towards mangrove conservation or restoration. Specifically, only Somalia and Equatorial Guinea have prepared explicit budgets for mangrove-specific actions. This reveals a lack of prioritization across the continent, amidst the fact that 16 of the 33 countries had included actions for mangrove ecosystems in their NDCs. Although 13 countries had prepared budgets for either forests or wetlands, and nine countries had budgets prepared for blue carbon or coastal ecosystems, it was not explicit whether these budgets covered mangrove-specific actions. One may assume that such budgets, especially those of blue carbon or coastal ecosystems, would include mangroves, but that might not be the case since these ecosystems also include seagrasses and salt marshes. Countries should specifically indicate the inclusion of mangrove ecosystems in their budgets for forests, wetlands, blue carbon, or coastal ecosystems to effectively acknowledge the role of mangroves as carbon sinks and natural barriers against storm surges (Comte et al., 2023). For example, Somalia's budget of USD 3.850 billion explicitly mentioned the inclusion of mangrove actions.

The inclusion of designated locations, number of hectares, and timelines for mangrove actions in NDCs demonstrates a tangible commitment to integrating mangroves into climate change strategies. This highlights the fact that it is not enough for countries to just mention mangrove actions in their climate change mitigation and adaptation plans. These actions need to be specific, measurable, achievable, relevant, and time-bound (SMART). From the 33 NDCs reviewed, only three countries (Sierra Leone, Nigeria, and Djibouti) identified proposed areas for mangrove conservation or restoration. This limited inclusion underscores a critical gap in spatial planning for mangrove management within NDCs. Sierra Leone's blue carbon initiative for the Sierra Leone River and Bonthe-Sherbro River Estuaries, highlighted in its NDCs, exemplifies a strategic approach that links mangrove and seagrass conservation to carbon sequestration objectives. Moreover, Nigeria's ambitious plan to protect and restore 13,012 ha of mangroves across the Niger Delta highlights the recognition of these ecosystems as crucial to combating widespread degradation in one of the most industrially impacted regions in Africa. Djibouti's focus on enhancing the resilience of local communities and mangroves in the Tadjourah coastal zone emphasizes the socio-ecological benefits of mangrove ecosystems in vulnerable coastal communities. These country-specific plans offer valuable models but also highlight the need for broader replication across the continent for mangrove-possessing countries.

Moreover, Senegal, Sierra Leone, Liberia, Nigeria, Equatorial Guinea, and Seychelles quantified their mangrove action targets in terms of hectares or percentages. This specificity is a critical step in operationalizing NDC commitments, as it provides measurable targets

against which progress can be tracked. For instance, Nigeria's inclusion of the exact hectares to be restored reflects a deeper integration of mangrove ecosystems into its NDC framework. Similarly, the efforts of Equatorial Guinea to outline hectares to be conserved or restored underscore a comprehensive approach that integrates ecological and spatial planning.

Timelines are another critical component of effective integration of mangrove actions in NDCs, offering a temporal framework for action and accountability. This lack of temporal specificity among most mangrove-possessing countries presents a significant barrier to assessing progress and ensuring accountability. Among the 16 countries with mangrove actions in their NDCs, only five countries (Senegal, Liberia, Benin, Equatorial Guinea, and Seychelles) included specific timelines. These timelines reflect varying levels of urgency and strategic planning among countries. Short-term timelines, as seen in Seychelles, Liberia, and Benin, highlight an immediate response to pressing climate challenges, while mid to longer-term goals, such as those of Equatorial Guinea, indicate a phased and sustainable approach or longer requisites to achieve them.

This study underscores that while the inclusion of mangrove actions in NDCs is commendable, it is imperative for countries to move beyond policy declarations and actively develop implementation-oriented strategies underpinned by robust mangrove research. Such strategies must be those that are at the heart of the dependent population's socio-cultural, economic, climate, and environmental reality (Dahdouh-Guebas et al., 2022). Effective realization of mangrove-related commitments requires not only sound policy but also active collaboration with local communities. As noted by Ofori et al. (2023), land tenure insecurity has been a significant driver of mangrove degradation and a major barrier to restoration success in Ghana. Local communities, many of whom consider mangrove forests as ancestral heritage, are often excluded from the planning stages of conservation programs. Without their participation, compensation, or access to alternative livelihoods, community members may continue unsustainable harvesting practices, or even undermine restoration efforts, for example, by setting fires that destroy mangrove seedlings during dry seasons (Ofori et al., 2023). Lovelock and Brown (2019) highlight that for mangrove restoration to be successful, it requires time frames of 5–10 years, building the trust, confidence, and willingness of local communities to participate in these projects. Moreover, it is important that up to 50 % of project budgets should be directed towards supporting this process.

Furthermore, mangrove-possessing countries must prioritize comprehensive assessment, both via remote sensing and ground-based surveys, to accurately determine the current extent, composition, and rate of mangrove loss. Such assessments should identify critical areas requiring urgent action, quantify restoration or conservation targets (in hectares), and establish realistic timelines for achieving these goals. To bolster these efforts, countries are encouraged to leverage international frameworks and partnerships, such as REDD+, the UN Decade on Ecosystem Restoration, and the Global Mangrove Alliance. These platforms offer access to technical expertise, financial resources, and policy guidance that can support countries in translating their NDC ambitions into concrete, measurable outcomes for mangrove ecosystem conservation and restoration.

4.1. Limitations of this study

Inasmuch as we focused on NDCs as the primary source of data for this research to promote standardized comparison among countries, we acknowledge that NDCs may not provide a complete account of current mangrove actions being documented or implemented across the various countries. At the time the NDCs were prepared, some mangrove-related initiatives may not have been documented or developed. Additionally, mangrove actions for climate change adaptation and mitigation presented in relevant government or non-governmental documents may not

be reflected in the NDCs.

This limitation presents perspectives for future research to explore mangrove actions documented or implemented by mangrove-possessing countries through a broader review of literature and in-depth interviews with relevant institutions. Such research would provide a more comprehensive understanding of efforts made by mangrove-possessing countries in Africa towards mangrove ecosystems and their role in climate change adaptation and mitigation.

5. Conclusion

The integration of mangrove ecosystems into African Nationally Determined Contributions (NDCs) remains a significant yet underutilized opportunity for advancing climate change mitigation and adaptation goals. While only a limited number of countries have explicitly outlined actions for mangrove conservation and restoration in their NDCs, the disparity in approaches reveals a mix of emerging awareness and persistent gaps in mangrove integration in NDCs. We present four specific and actionable recommendations for countries to enhance the integration of mangrove actions in their NDCs.

1. Policymakers should work closely with research institutions to translate scientific findings into actionable policy briefs for NDC updates. Researchers should engage in policy dialogues to ensure emerging mangrove research is accessible, timely, and tailored to national climate contexts. Moreover, there should be follow-ups with monitoring visits to verify the implementation of these updated NDCs and the assessment of obstacles and facilitating factors.
2. As countries prepare to submit their updated NDCs in September 2025, they are encouraged to utilize the four newly developed policy guidance briefs by the Mangrove Breakthrough NDC Task Force, which complement this study. These briefs, in conjunction with this study, will help countries formulate science-based, measurable, and actionable NDC targets focused on mangrove conservation, restoration, sustainable management, and financing.
3. Countries such as Sierra Leone, Nigeria, Djibouti, Senegal, Liberia, and Equatorial Guinea, which are already demonstrating strong mangrove integration in their NDCs, should be supported to act as regional knowledge hubs. Governments and research institutions in these countries can come together to facilitate peer-learning platforms and exchange visits to scale best practices continent-wide.
4. Governments, NGOs, local communities, and scientists should jointly identify and map priority areas for mangrove restoration or protection in their respective countries and invest in building technical capacity to implement blue carbon and ecosystem-based approaches.
5. National climate finance strategies should create dedicated budget lines for mangrove conservation and restoration to ensure tangible support for implementation. NGOS, researchers, and technical experts can work with ministries to cost out mangrove action plans and identify potential co-financing opportunities (e.g., blue carbon markets, green bonds).

CRediT authorship contribution statement

Samuel Appiah Ofori: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Data curation, Conceptualization. **Jean Hugé:** Writing – review & editing, Supervision. **Setondé Constant Gnansounou:** Writing – review & editing, Methodology, Investigation, Data curation. **Arimatéa C. Ximenes:** Writing – review & editing, Visualization, Methodology, Investigation. **Frederick Asante:** Writing – review & editing, Visualization. **M'koumfida Bagbohouna:** Writing – review & editing, Investigation. **Adrien Comte:** Writing – review & editing, Investigation. **Esméralda Longépée:** Writing – review & editing, Visualization, Investigation. **Kipkorir Sigi Lang'at:** Writing – original draft, Investigation. **Salomão Olinda Bandeira:** Writing – review & editing, Investigation. **Derrick**

Omollo: Writing – review & editing, Investigation. **Amarachi Paschalline Onyena:** Writing – review & editing, Investigation. **Kabari Sam:** Writing – review & editing, Investigation. **Amina Juma Hamza:** Writing – review & editing, Investigation. **Adel Zeggaf Tahiri:** Writing – review & editing, Investigation. **Daf Sehla Daf:** Writing – review & editing, Investigation. **Khady Diouf Goudiaby:** Writing – review & editing, Investigation. **Emmanuel Temitope Olatunji:** Writing – review & editing, Investigation. **Claire Golléty:** Writing – review & editing, Investigation. **Elie Antoine Padonou:** Writing – review & editing, Investigation. **Farid Dahdouh-Guebas:** Writing – review & editing, Supervision, Project administration.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors extend their gratitude to the United Nations Framework Convention on Climate Change (UNFCCC) for creating a registry of the Nationally Determined Contributions (NDCs) of all participating countries.

Data availability

Data will be made available on request.

References

- Adame, M.F., Cormier, N., Taillardat, P., Iram, N., Rovai, A., Sloey, T.M., Yando, E.S., et al., 2024. Deconstructing the mangrove carbon cycle: gains, transformation, and losses. *Ecosphere* 15 (3), e4806. <https://doi.org/10.1002/ecs2.4806>.
- Africa Center for Strategic Studies, 2022. Rising sea levels besieging Africa's booming coastal cities. Retrieved from. <https://africacenter.org/spotlight/rising-sea-levels-besieging-africas-booming-coastal-cities-lagos-dakar-alexandria-maputo-nile/#:~:text=African%20coastlines%20have%20experienced%20a,be%20limited%20to%200.4%20meters>.
- Alongi, D.M., 2022. Impacts of climate change on blue carbon stocks and fluxes in mangrove forests. *Forests* 13, 149. <https://doi.org/10.3390/f13020149>.
- Alves, B., Angnuureng, D.B., Morand, P., et al., 2020. A review on coastal erosion and flooding risks and best management practices in West Africa: what has been done and should be done. *J. Coast Conserv.* 24, 38. <https://doi.org/10.1007/s11852-020-00755-7>.
- Bunting, P., Rosenqvist, A., Hilarides, L., Lucas, R.M., Thomas, N., Tadono, T., Worthington, T.A., Spalding, M., Murray, N.J., Rebelo, L.-M., 2022. Global mangrove extent change 1996–2020. *Remote Sens.* 14 (15). <https://doi.org/10.3390/rs14153567>. Article 3567.
- Choudhary, B., Dhar, V., Pawase, A.S., 2024. Blue carbon and the role of mangroves in carbon sequestration: its mechanisms, estimation, human impacts and conservation strategies for economic incentives. *J. Sea Res.* 199, 102504. <https://doi.org/10.1016/j.seares.2024.102504>.
- Comte, A., Cormier-Salem, M.-C., Guillotreau, P., Manouvrier, S., Proisy, C., et al., 2023. Blue Carbon Credits: A Lot of Promises but Even More Uncertainties for the Global South. *Policy Brief, COP28, UAE*, pp. 1–4. (hal-04425664).
- Dahdouh-Guebas, F., Friess, D.A., Lovelock, C.E., Connolly, R.M., Feller, I.C., et al., 2022. Cross-cutting research themes for future mangrove forest research. *Nat. Plants* 8, 1131–1135. <https://doi.org/10.1038/s41477-022-01245-4>.
- Dahdouh-Guebas, F., Jayatissa, L.P., Di Nitto, D., Bosire, J.O., Lo Seen, D., Koedam, N., 2005. How effective were mangroves as a defence against the recent tsunami? *Curr. Biol.* 15 (12), R443-R447. <https://doi.org/10.1016/j.cub.2005.06.008>.
- Dahdouh-Guebas, F., Cannicci, S., 2021. Mangrove restoration under shifted baselines and future uncertainty. *Front. Mar. Sci.* 8. <https://doi.org/10.3389/fmars.2021.799543>. Article 799543.
- Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M., Kanninen, M., 2011. Mangroves among the most carbon-rich forests in the tropics. *Nat. Geosci.* 4 (5), 293–297. <https://doi.org/10.1038/ngeo1123>.
- FAO, 2023. The world's mangroves 2000–2020. <https://doi.org/10.4060/cc7044en>.

- Ferdinand, M., 2018. Subnational climate justice for the French outre-mer: postcolonial politics and geography of an epistemic shift. *Island Studies Journal* 13 (1), 119–134. <https://doi.org/10.24043/isj.49>.
- Febissie, K., Chia, E., Enongene, K., Oeba, V.O., 2019. Agriculture, forestry and other land uses in nationally determined contributions: the outlook for Africa. *Int. For. Rev.* 21 (S1), 1–11. <https://doi.org/10.1505/146554819827167484>.
- Gallo, N.D., Victor, D.G., Levin, L.A., 2017. Ocean commitments under the paris agreement. *Nat. Clim. Change* 7 (11), 833–838. <https://doi.org/10.1038/nclimate3422>.
- Goldberg, L., Lagomasino, D., Thomas, N., Fatoyinbo, T., 2020. Global declines in human-driven mangrove loss. *Glob. Change Biol.* 26 (10), 5844–5855. <https://doi.org/10.1111/gcb.15275>.
- Hagger, V., Worthington, T.A., Lovelock, C.E., Adame, M.F., Amano, T., Brown, B.M., Friess, D.A., Landis, E., Mumby, P.J., Morrison, T.H., O'Brien, K.R., Wilson, K.A., Zganiar, C., Saunders, M.I., 2022. Drivers of global mangrove loss and gain in social-ecological systems. *Nat. Commun.* 13 (1), 6373. <https://doi.org/10.1038/s41467-022-33962-x>.
- Hamilton, J., Kasprzyk, K., Cifuentes-Jara, M., Granziera, B., Gil, L., Wolf, S., Starling, G., Zimmer, A., Hickey, T., 2023. Blue carbon and nationally determined contributions. *Conservation International, the Nature Conservancy, NDC Partnership, MCC Sustainable Futures, the Pew Charitable Trusts, second ed.*
- Heck, N., Goldberg, L., Andradi-Brown, D.A., Campbell, A., Narayan, S., Ahmadia, G.N., Lagomasino, D., 2024. Global drivers of mangrove loss in protected areas. *Conserv. Biol.* 38, e14293. <https://doi.org/10.1111/cobi.14293>.
- Hehmeyer, A., Vogel, J., Martin, S., Bartlett, R., 2019. *Enhancing nationally determined contributions through protected areas*. WWF. Retrieved from. <https://wwf.panda.org/es/2349384/Enhancing-NDCs-Through-Protected-Areas>.
- Ho, Y.-S., Mukul, S.A., 2021. Publication performance and trends in mangrove forests: a bibliometric analysis. *Sustainability* 13 (22). <https://doi.org/10.3390/su132212532>. Article 12532.
- Horstman, E.M., Dohmen-Janssen, C.M., Narra, P.M.F., van den Berg, N.J.F., Siemerink, M., Hulscher, S.J.M.H., 2014. Wave attenuation in mangroves: a quantitative approach to field observations. *Coast. Eng.* 94, 47–62. <https://doi.org/10.1016/j.coastaleng.2014.08.005>.
- Jallow, B.P., Barrow, M.K.A., Leatherman, S.P., 1996. Vulnerability of the coastal zone of the Gambia to sea level rise and development of response strategies. *Clim. Res.* 6 (2), 165–177. <https://doi.org/10.3354/cr006165>.
- Kairo, J.G., Hamza, A.J., Wanjuiru, C., 2018. Mikoko pamoja: a demonstrably effective community-based blue carbon project in Kenya. In: Laffoley, D., Grimsditch, G. (Eds.), *A Blue Carbon Primer: the State of Coastal Wetland Carbon Science, Practice and Policy*. CRC Press, p. 10. <https://doi.org/10.1201/9780429435362-24>.
- Kodikara, K.A.S., Mukherjee, N., Jayatissa, L.P., Dahdouh-Guebas, F., Koedam, N., 2017. Have mangrove restoration projects worked? An in-depth study in Sri Lanka. *Restor. Ecol.* 25 (5), 705–716. <https://doi.org/10.1111/rec.12492>.
- Leal, M., Spalding, M.D., 2024. The State of the World's Mangroves 2024. Global Mangrove Alliance. <https://doi.org/10.5479/10088/119867>.
- Lecerf, M., Herr, D., Elverum, C., Delrieu, E., Picourt, L., 2021. *Coastal and Marine Ecosystems as Nature-based Solutions in New or Updated Nationally Determined Contributions. Ocean & Climate Platform, Conservation International, IUCN, Rare, the Nature Conservancy, Wetlands International, and WWF*.
- Liu, X., Fatoyinbo, T.E., Thomas, N.M., Guan, W.W., Zhan, Y., Mondal, P., Lagomasino, D., Simard, M., Trettin, C.C., Deo, R., Barenblatt, A., 2021. Large-scale high-resolution coastal mangrove forests mapping across West Africa with machine learning ensemble and satellite big data. *Front. Earth Sci.* 8.
- Lovelock, C.E., Brown, B.M., 2019. Land tenure considerations are key to successful mangrove restoration. *Nat. Ecol. Evol.* 3 (8), 1135. <https://doi.org/10.1038/s41559-019-0942-y>.
- Mather, A.A., Stretch, D.D., 2012. A perspective on sea level rise and coastal storm surge from southern and eastern Africa: a case study near durban, South Africa. *Water* 4 (1), 237–259. <https://doi.org/10.3390/w4010237>.
- Mayson, J.C.L., 2018. The present state of the Liberian coast: contributions to coastal vulnerability and coastal masterplan. Retrieved from. https://upcommons.upc.edu/bitstream/handle/2117/130300/Theesis_final_version.pdf?sequence=1&isAllowed=y.
- Mazda, Y., Magi, M., Ikeda, Y., et al., 2006. Wave reduction in a mangrove forest dominated by *Sonneratia* sp. *Wetlands Ecol Manage* 14, 365–378. <https://doi.org/10.1007/s11273-005-5388-0>.
- Mostefaoui, M., Ciais, P., McGrath, M.J., Peylin, P., Patra, P.K., Ernst, Y., 2024. Greenhouse gas emissions and their trends over the last 3 decades across Africa. *Earth Syst. Sci. Data* 16, 245–275. <https://doi.org/10.5194/essd-16-245-2024>.
- Murdiyarsa, D., Purbopuspito, J., Kauffman, J.B., et al., 2015. The potential of Indonesian mangrove forests for global climate change mitigation. *Nat. Clim. Change* 5 (12), 1089–1092. <https://doi.org/10.1038/nclimate2734>.
- Naidoo, G., 2023. The mangroves of Africa: a review. *Mar. Pollut. Bull.* 190, 114859. <https://doi.org/10.1016/j.marpolbul.2023.114859>.
- Ndour, A., Laïbi, R.A., Sadio, M., Degbe, C.G.E., Diaw, A.T., Oyédé, L.M., Anthony, E.J., Dussouillez, P., Samiou, H., Diéye, E.B., 2018. Management strategies for coastal erosion problems in West Africa: analysis, issues, and constraints drawn from the examples of Senegal and Benin. *Ocean Coast Manag.* 156, 92–106. <https://doi.org/10.1016/j.ocecoaman.2017.09.001>.
- Nijamdeen, T.W.G.F.M., Ratsimbazafy, H.A., Kodikara, K.A.S., Nijamdeen, T.W.G.F.A., Thahira, T., Peruzzo, S., Dahdouh-Guebas, F., Hugé, J., 2023. Mangrove management in Sri Lanka and stakeholder collaboration: a social network perspective. *J. Environ. Manag.* 330, 117116. <https://doi.org/10.1016/j.jenvman.2022.117116>.
- Ofori, S.A., Asante, F., Boateng, T.A.B., Dahdouh-Guebas, F., 2023. The composition, distribution, and socio-economic dimensions of Ghana's mangrove ecosystems. *J. Environ. Manag.* 345. <https://doi.org/10.1016/j.jenvman.2023.118622>. Article 118622.
- Ofori, S.A., Cobbina, S.J., Obiri, S., 2021. Climate change, land, water, and food security: perspectives from Sub-Saharan Africa. *Front. Sustain. Food Syst.* 5. <https://doi.org/10.3389/fsufs.2021.680924>. Article 680924.
- Osti, R., Tanaka, S., Tokioka, T., 2011. The importance of mangrove forests in tsunami disaster mitigation. *Disasters* 33 (2), 203–213. <https://doi.org/10.1111/j.1467-7717.2008.01070.x>.
- QGIS Development Team, 2024. QGIS Geographic Information System. Open Source Geospatial Foundation Project, O-Prizren. Available at:, Version 3.34.. <http://qgis.org>.
- Röser, F., Widerberg, O., Höhne, N., Day, T., 2020. Ambition in the making: analysing the preparation and implementation process of the Nationally Determined Contributions under the Paris Agreement. *Clim. Policy* 20 (4), 415–429. <https://doi.org/10.1080/14693062.2019.1708697>.
- Sabeel, R.A., 2015. Variation in Distribution of Sudanese Mangroves and Their Ecological Significance for Benthic Fauna. Universiteit Ghents [Unpublished doctoral dissertation].
- Sam, K., Zabey, N., Gbaa, N.D., Ezuriuke, J.C., Okoro, C.M., 2023. Towards a framework for mangrove restoration and conservation in Nigeria. *Regional Studies in Marine Science* 66. <https://doi.org/10.1016/j.rsma.2023.103154>. Article 103154.
- Sasmito, S.D., Basyuni, M., Kridalaksana, A., et al., 2023. Challenges and opportunities for achieving sustainable development goals through restoration of Indonesia's mangroves. *Nature Ecology & Evolution* 7, 62–70. <https://doi.org/10.1038/s41559-022-01926-5>.
- Sidik, F., Lawrence, A., Wagey, T., Zamzani, F., Lovelock, C.E., 2023. Blue carbon: a new paradigm of mangrove conservation and management in Indonesia. *Mar. Pol.* 147. <https://doi.org/10.1016/j.marpol.2022.105388>. Article 105388.
- Song, S., Ding, Y., Li, W., et al., 2023. Mangrove reforestation provides greater blue carbon benefit than afforestation for mitigating global climate change. *Nat. Commun.* 14. <https://doi.org/10.1038/s41467-023-36477-1>. Article 756.
- World Bank, 2024. Somalia Systematic Country Diagnostic Update, June 2023: Accelerating the Building of Inclusive Institutions for Resilience and Jobs. © World Bank. <http://hdl.handle.net/10986/41056>. License: CC BY-NC 3.0 IGO.
- United Nations Framework Convention on Climate Change (UNFCCC), 2015. Paris agreement. Retrieved from. <https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement>.
- Zimmer, M., Ajonina, G.N., Aldrie, A.A., et al., 2022. When nature needs a helping hand: different levels of human intervention for mangrove (Re-)establishment. *Frontiers in Forests and Global Change* 5. <https://doi.org/10.3389/ffgc.2022.784322>. Article 784322.