Coastal Wetlands in National Greenhouse Gas Inventories

Advice on reporting emissions and removal from management of Blue Carbon ecosystems

Authors

Carly Green[1], Catherine E. Lovelock[2], Sigit Sasmito[2], Valerie Hagger[2] and Stephen Crooks[3]

[1] Environmental Accounting Services, Wanaka, New Zealand

[2] The University of Queensland, Brisbane, QLD, Australia

[3] Silvestrum Climate Associates, San Francisco, CA, USA

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Reviewers

1. Andy Stevens, CSIRO
2. Aradhana Singh, Ministry of Economy, Government of Fiji
3. Bridget Kennedy, Conservation International
4. Daniel Murdiyarso, CIFOR
5. David Pepper, Department of Industry, Science, Energy and Resources, Government of Australia
6. Deborah Sue, Ministry of Forestry, Government of Fiji
7. Deepitika Chand, Ministry of Economy, Government of Fiji
8. Franky Zamzani, Ministry of Environment and Forestry, Government of Indonesia
9. Dr Frida Sidik, Ministry of Marine Affairs and Fisheries, Government of Indonesia
10. Dr Haruni Krisnawati, Ministry of Environment and Forestry, Government of Indonesia
11. Ilai Tulele, Ministry of Forestry, Government of Fiji
12. Irawan Asaad, Ph.D. Ministry of Environment and Forestry, Government of Indonesia
13. Jeanette Mani, Ministry of Economy, Government of Fiji
14. Mat Vanderklift, CSIRO
15. Mohammed Shorab, Ministry of Forestry, Government of Fiji
16. Dr Novi Susetyo Adi, Ministry of Marine Affairs and Fisheries
17. Tertius de Kluyver, Department of Industry, Science, Energy and Resources, Government of Australia
18. Vili Tupua, Ministry of Forestry, Government of Fiji
19. Dr Virni Arifanti, Ministry of Environment and Forestry, Government of Indonesia
20. Dr Yaya Ulumuddin, Indonesian Institute of Sciences, Government of Indonesia

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Reviewers: Irawan Asaad (Ministry of Environment and Forestry, Indonesia), Novi Susetyo Adi (Ministry of Marine Affairs and Fisheries, Indonesia), Frida Sidik (Ministry of Marine Affairs and Fisheries, Indonesia), Yaya Ulumuddin (Indonesia Institute of Sciences), Daniel Murdiyarso (Center for International Forestry Research, CIFOR), Andy Steven (Commonwealth Scientific Industrial Research Organisation, Australia), Mat Vanderklift (Commonwealth Scientific Industrial Research Organisation, Australia), Jeanette Mani (Ministry of Economy, Fiji), Bridget Kennedy (Conservation International, Fiji), Lisa Beers (Silvestrum Climate Associates).

Acronyms

AFOLU	Agriculture, Forestry and Other Land-use
AGB	Above-Ground Biomass
BGB	Below-Ground Biomass
BTR	Biennial Transparency Report
BUR	Biennial Update Report
C	Carbon
C-CAP	Coastal Change Analysis Program
CH4	Methane
CIFOR	Center for International Forestry Research
CO2	Carbon Dioxide
DOM	Dead Organic Matter
EF	Emission Factor
ERPD	Emission Reduction Program Document
FAO	Food and Agriculture Organisation of the United Nations
FREL/ FRL	Forest Reference Emission Level/Forest Reference Level
FullCAM	Full Carbon Accounting Model
GFOI	Global Forest Observations Initiative
GHG	Greenhouse Gas
HAT	Highest Astronomical Tide
IPCC	Intergovernmental Panel on Climate Change
KCA	Key Category Analysis
LANDSAT	Land Satellite (US Satellite series)
LCDI	Low Carbon Development Initiative
LED	Low Emissions Development Strategy
LULUCF	Land-use, Land-Use Change and Forestry
MESCAL	Mangrove Ecosystems for Climate Change Adaptation and Livelihoods
MSL	Mean Sea Level
MRV	Measurement, Reporting, and Verification
NDC	Nationally Determined Contribution

NGGI	National Greenhouse Gas Inventory
N2O	Nitrous oxide
NOAA	National Oceanic and Atmospheric Administration
QA/QC	Quality Assurance / Quality Control
REDD+	Reducing Emissions from Deforestation and forest Degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks (REDD+).
SDG	Sustainable Development Goals
SWAMP	Sustainable Wetlands Adaptation and Mitigation Program
TACCC	Transparency, Accuracy, Consistency, Comparability, Completeness
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	The United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

Activity Data: Geographical data showing the types of land coverage and use in a given area.

Afforestation: The direct human-induced conversion of land that has not been forested for a period of at least 50 years to forested land through planting, seeding and/or the human-induced promotion of natural seed sources (UNFCCC, 2001).

Attribution: The process of associating observed land cover and cover changes with land-use and land-use change. Because different management and disturbance types have different impacts on carbon stocks and greenhouse gas emissions, knowledge of the cause of disturbance is needed not only to estimate areas of land-use and land-use change but also to estimate the associated greenhouse gas emissions and removals.

Blue Carbon: The carbon stored in mangroves, tidal marshes, and seagrass meadows within the soil, the living biomass above ground (leaves, branches, stems), the living biomass below ground (roots), and the non-living biomass (litter and dead wood).

Carbon Stock: The total amount of organic carbon stored in an ecosystem of a known size. A carbon stock is the sum of one or more carbon pools.

Coastal wetland: Wetland at or near the coast that is influenced by brackish/saline water and/or astronomical tides.

Drainage: Mangroves and tidal marshes have been diked and drained to create pastures, croplands and settlements (IPCC, 2014).

Emission Factors: A term used to describe changes in the carbon content of a pre-defined area due to change in land coverage and use (i.e., conversion from mangroves to shrimp ponds) or changes within a land-use type (i.e., nutrient enrichment of seagrass).

Extraction: (a) Excavation of saturated soils leading to unsaturated (drained) soils and removal of biomass and dead organic matter; and (b) Excavation during the “construction” phase of aquaculture and salt production ponds in mangroves and tidal marshes followed by the “use” of these facilities.

Fish cages or pens: Types of enclosures at the water surface or fixed to the seabed that maintain a free exchange of water and fine particles and used to cultivate aquatic organisms for human consumption.

Fish pond: Ponds constructed in brackish or saline water, designed to retain and culture fish for commercial production (aquaculture).

Forest management in mangroves: Removal of wood in mangrove forests for fuelwood, charcoal, and construction, ranging from extensive forest clearing to more moderate, selective harvesting of individual trees, or to minimally invasive activities such as bark removal (IPCC, 2014).

Key Category: A key category is one that is prioritised within the national inventory system because its estimate has a significant influence on a country’s total inventory of greenhouse gases in terms of the absolute level, the trend, or the uncertainty in emissions and removals. Whenever the term key category is used, it includes both source and sink categories (IPCC, 2006).

Mangrove: A coastal wetland that has trees able to live in areas that are tidally flooded by brackish/saline water.

Methodological change: A methodological change in a category is a switch to a different tier from the one previously used (e.g., replace Tier 1 default method with nationally specific data as it becomes available). This situation is quite common in national greenhouse gas inventory (NGGI).

Methodological refinement: A methodological refinement occurs when an inventory compiler uses the same tier to estimate emissions but applies it using a different data source or a different level of aggregation. An example of a refinement would be if new data permit further disaggregation of mangrove forests, so that resulting strata are more homogenous or applies a more accurate emission factor. In this case, the estimate is still being developed using a Tier 2 method, but it is applied at a more detailed level of disaggregation. Another possibility is that data of a similar level of aggregation but higher quality data could be introduced, due to improved data collection methods.

Nationally Determined Contribution (NDCs): National climate plans highlighting climate actions, including climate related targets, policies and measures governments aim to implement under the Paris Agreement (UNFCCC, 2001). NDCs can cover a broad scope of activities with no sectorial restrictions. NDCs must be transparent, quantifiable, comparable, verifiable and ambitious. They must be developed until 2020 and will be implemented afterwards.

Quality assurance (QA): A planned system of review procedures conducted by personnel not directly involved in the inventory and performed on a completed inventory.

Quality control (QC): A planned system of routine activities to assess, improve or maintain the quality of the inventory as it is being compiled.

Rehabilitation: Reinstating a level of ecosystem functioning for renewed and ongoing provision of ecosystem services potentially derived from non-native ecosystems (Gann et al., 2019).

Restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Gann et al., 2019).

Rewetting: Hydrologic modifications to reverse drainage or remove impoundments or other obstructions to hydrologic flow (e.g., levee breach), required for vegetation reestablishment and/or creation of conditions conducive to purposeful planting of vegetation that is characteristic of coastal wetland (IPCC, 2014).

Revegetation: Natural recolonisation, direct seeding, and purposeful planting.

Reforestation: The direct human-induced conversion of non-forested land to forested land through planting, seeding, and/or the human-induced promotion of natural seed sources, on land that was forested but that has been converted to non-forested land (UNFCCC, 2001).

Salt production: The production of salt by evaporating brackish or saline tidal water.

Stratification: A technique used to divide large heterogeneous sites (which require many samples to account for variation) into smaller more homogeneous areas (where fewer samples are needed) and is also useful when field conditions, logistical issues, and resource limitations prevent dense sampling regimes.

Seagrass meadow: Coastal wetland vegetated by seagrass species (rooted, flowering plants), permanently or tidally covered by brackish/saline water.

Soil Organic Carbon: Carbon component of the soil organic matter. The amount of soil organic carbon depends on soil texture, climate, vegetation, and historical and current land-use/ management.

Tidal freshwater wetland: Wetland inundated or saturated for all or part of the year by tidal freshwater. The upper boundary is recognised as the landward extent of tidal inundation.

Tidal marsh: Marsh inundated or saturated for all or part of the year by tidal freshwater or brackish/saline water. The upper boundary is recognised as the landward extent of tidal inundation.

Tier: A tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate.

1. Executive summary

Coastal wetlands such as mangroves, tidal marshes, and seagrasses are among the most biodiverse environments on the planet and form a critical bridge between land and sea, providing a home for countless species and a wealth of vital ecosystem services (**Figure 1**). The value of sustainably managing and ensuring the integrity of coastal wetland ecosystems is recognised by the United Nations Framework Convention on Climate Change (UNFCCC)[1] and its Paris Agreement[2].

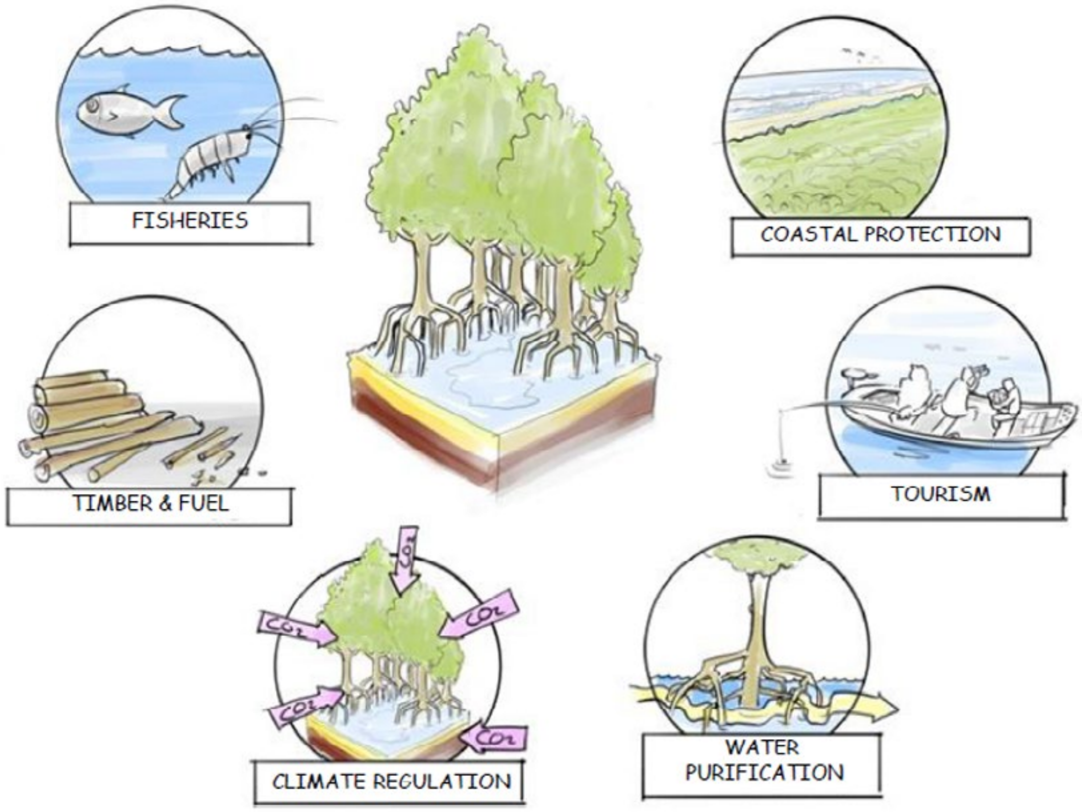


Figure 1: Wide ranging ecosystems services provided by coastal wetland ecosystems (Worthington, Andradi-Brown, et al., 2020)

By incorporating coastal wetland (or blue carbon) ecosystems into National Greenhouse Gas Inventories (NGGIs), countries can improve the continual monitoring and reporting of the condition of these ecosystems and recognise the valuable contribution they provide to climate change mitigation and adaptation.

1 UNFCCC Article 4.1 (commitments): “all Parties shall promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems.”

2 Paris Agreement (preambular):“Noting the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity...”. and also mentioned in Paris Agreement Article 5.1: Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases as referred to in Article 4, paragraph 1 (d), of the Convention, including forests.

The advice presented here aims to assist countries who chose to include coastal wetlands in their NGGI to measure and report coastal wetlands' benefits by drawing on relevant:

- Sections of the 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (IPCC, 2014) (referred to as 2013 Wetlands Supplement)[3].
- Sections of the 2006 IPCC Guidelines for National Greenhouse Gas Inventorie (IPCC, 2006)[4].
- Considerations on inclusion of impounded waters under the 2019 Refinement to the IPCC 2006 Guidelines for National Greenhouse Gas Inventories in Chapter 7 Wetlands (IPCC, 2019) (referred to as 2019 Wetlands Refinement).
- Experiences of countries reporting emissions and removals from coastal wetlands in NGGI, and countries developing national forest monitoring systems for Reducing Emissions from Deforestation and Forest Degradation (REDD+) measurement, reporting and verification (MRV).

Topics covered include institutional arrangements, design decisions, data sources, methods and MRV considerations related to including coastal wetlands in NGGIs. Key matters addressed include activity based reporting, multipurpose reporting frameworks to meet broader policy objectives, focusing resources (both human and financial) on key categories (and subcategories) when collecting nationally specific data, considerations when utilising global datasets, time series consistency, attribution, and the importance of internal processes such as quality control, completeness, time series consistency, uncertainty estimation and documentation in meeting good practice MRV requirements.

These topics are considered in a practical context in a demonstration of complier decision-making related to the inclusion of mangroves in NGGIs (**Appendix B**). This demonstration presents an example of how to apply the 2013 Wetlands Supplement and the considerations to make at each stage with links back to the detailed advice covered in the chapters.

This document aims to:

- Provide advice on how to incorporate coastal wetland ecosystems into NGGIs, including how they may relate to consistency in reporting between activity based (e.g., REDD+) and sector based (e.g., Agriculture, Forestry and Other Land-use (AFOLU) and Wetlands) reporting.
- Clarify the different approaches, methods and tiers by which coastal wetland ecosystems can be incorporated within national reporting to the UNFCCC and its Paris Agreement.

3 The 2013 Wetlands Supplement addresses the absence in the 2006 IPCC Guidelines of any guidance on how to treat anthropogenic emissions and removals associated with specified human activities that affect coastal wetland ecosystems, including mangrove forests, tidal marshes and seagrass meadows. Emissions factors and methodologies are provided for management of mangrove forests (i.e., harvesting), rewetting, revegetation and creation, aquaculture and drainage.

4 Guidance on time series consistency and consistent representation of lands within the 2006 IPCC Guidelines are relevant to coastal wetland ecosystems. Useful updates related to these topics in the 2019 Wetlands Refinement are also included in advice within this document.

The advice is targeted at:

- Inventory compilers responsible for the design and implementation of decisions to meet MRV requirements.
- Government agencies responsible for national data collection and collation related to coastal wetlands.
- Policy advisors interested in monitoring effectiveness of land-use policy decisions.
- Research institutes contributing to national datasets for greenhouse gas (GHG) inventories.

For ease of navigation of the advice readers should seek out the following chapters:

Question	Executive summary	Chapters
WHY report on coastal wetlands	Compilers, Policy Advisers	2
HOW to report coastal wetlands	Compilers, Data Collection Agencies, Researchers	3,4
WHAT to include in coastal wetland reports	Compilers, Data Collection Agencies	5,6

Key messages presented throughout each chapter are summarised in **Table 1: Key messages and where they are addressed** to assist readers to navigate to the content most relevant to their needs. These key messages are enhanced by country case studies aimed at showcasing institutional, technical and methodological aspects related to incorporating coastal wetland ecosystems into NGGIs and other national reporting objectives.

Table 1: Key messages and where they are addressed

Key Messages	Section/Case Study
Relevance to National Greenhouse Gas Inventory	
By 2024 at least (in accordance with reporting requirements under the Paris Agreement), adopt the 2013 Wetlands Supplement including coastal wetlands in NGGI and communications.	Section 2.2
Formalising institutional arrangements can facilitate measurement, reporting and verification.	Section 2.2 and Box 1: Formalising institutional arrangements in support of measurement, reporting and verification
Developing working groups on specific technical issues can be an effective way of addressing data and capacity gaps.	Section 2.2 and Box 14 Data sharing among government departments in Indonesia to integrate national and sub-national data sources

Key Messages	Section/Case Study
Relevance to Forest Reference Emissions Levels/Forest Reference Levels (FREL/FRL)	
Inclusion of mangroves in REDD+ is dependent on the national definition of Forest Lands.	Section 2.3
Where mangrove areas that meet the definition of forest and have been included in REDD+ FREL/FRL, countries can report these same mangrove lands under the Forest Land category in the NGGI for consistency, as opposed to the Wetland category. However, shrub mangroves can remain in the Wetland category.	Section 2.3 and Box 2: Mangroves under Forest Reference Emission Level (FREL) in Indonesia
A stepwise approach incorporating improved data or methodologies can entail improvements to the NGGI, as well as FREL/FRL estimates, to maintain mutual consistency.	Section 2.3 and Box 3**:** The stepwise inclusion of mangrove ecosystems in Fiji's Forest Reference Emissions Level (FREL) / Forest Reference Level (FRL)
Relevance to broad policy objectives	
Inclusion of Coastal Wetlands in the national policy dialogue can enable appropriate management recognition.	Section 2.4 and Box 4: Mangrove Ecosystems for Climate Change Adaptatio and Livelihoods (MESCAL) project, Fiji
Land representation	
It is recommended to monitor other marine ecosystems, although there is currently no requirement to do so.	Section 3.1 and Box 5: Queensland Government Wetland Classification System (DES, 2013)
Where mangroves (or sub-strata of mangrove ecosystems) do not meet the definition of forest, they can be reported under the Wetlands category in the NGGI.	Sections 2.3 and 3.1
Seagrasses may not fall under typical national land representation rules posing challenges for inclusion. Defining the concept of 'coastal land' and its seaward limits can assist overcoming such challenges or track as an activity basis outside of the land representation.	Section 3.1 and Box 6: Experimenting with incorporating seagrass in national greenhouse gas inventory in Australia.
Stratification	
Adopt stratification criteria that relates to the variable being measured such as ecosystems, carbon pools, and land management practices/activities.	Section 3.2 and Box 7: Stratification choices for coastal wetlands
Aim to balance strata size and number with desired accuracy, required time, and available resources.	Section 3.2 and Table 5: Examples of stratifying coastal wetlands

Key Messages	Section/Case Study
Methods, approaches and tiers	
Including coastal wetlands in NGGI is aided by Tier 1 default data or country specific data (Tier 2). The 2013 Wetlands Supplement removes any data related barrier to the inclusion of coastal wetlands in NGGIs.	Section 3.4
Including mangroves in REDD+ reporting may require national emissions factors or carbon stocks and spatially explicit activity data generated from remotely sensed data.	Section 3.3
Estimates include both emissions and removals related to land-use change.	Section 3.4
Key category analysis	
It is recommended to conduct a Tier 1 key category analysis using methods and default emission/removal factors available in the 2013 Wetlands Supplement as a first step for inclusion of coastal wetlands in the NGGIs.	Section 3.5 and Box 8: Example of a key category level assessment (Approach 1)
Identified key categories (i.e., activities or carbon pools) should be the focus of further development over time in a stepwise continuous improvement toward higher Tier reporting.	Section 3.5
Relevant carbon pools and gases	
Soil carbon stock changes are likely to be a key pool in coastal wetlands and in such cases could be a priority for collecting Tier 2 national data. In the absence of national data, Tier 1 default data and methods can be applied as an interim measure.	Section 3.6 and Box 9: Incremental improvement of estimates of change in mangrove soil carbon in Australia
In situations where national data is not available it is good practice to apply default values opposed to simply omitting the carbon pool. This applies to all land categories.	Sections 4.2 and 4.3
Emissions and removals within the five carbon pools are reported in the land category to which the land cover has been assigned.	Sections 4.2 and 4.3
Activity-based versus managed land proxy approach	
There are pros and cons for adopting either a managed land proxy or the activity-based approach. National conditions and preferences will be the driving influence for the methodological selection.	Section 4.1 and Box 10: Inclusion of coastal wetlands into the United States national greenhouse gas inventory

Key Messages	Section/Case Study
Land-use categories	
Spatially and temporally explicit activity data can facilitate use of higher Tier methods for key categories such as the soil carbon pool.	Section 4.2
Sampling soil carbon to 1 m is consistent with a number of sampling protocols, however in coastal wetlands Tier 2 method may warrant analysis to deeper depths.	Sections 4.3.2 and 4.3.3 Estimating emissions and removals from forest management and extraction
Default emission factors	
Coastal wetland ecosystems can be included in NGGIs using Tier 1 default data from the 2013 Wetlands Supplement rather than omitting them because of a lack of national data.	Section 5.1, Table 15: Variables required in the estimation of emissions and removals from coastal wetland ecosystems, and Table 16: Summary table of default emission factors for activities in coastal wetlands
National data sources	
Mapping the spatial extent and change of coastal wetlands through time is a good starting point for developing national data. This may include building appropriate technical and institutional capacity for data access and processing.	Section 5.2
National data sources can be used in conjunction with Tier 1 default data and global data sources to enable the inclusion of coastal wetlands into NGGIs in a stepwise approach.	Section 5.2 and Box 13: Combining tiered approaches to include mangroves and seagrass in national greenhouse gas inventory in Fiji
National data sources may be available from government agencies, non-government organisations, and research institutions from different regions and time steps for use in estimating emissions from activities in coastal wetlands.	5.2 and Box 14: Data sharing Section among government departments in Indonesia to integrate national and sub-national data source
There is complexity in developing activity data for seagrass meadows but high value in doing so, beyond NGGI reporting.	Section 5.2 Box 13 and Box 14
Global data sources	
A range of global data sources are available that can be used to estimate the distribution of coastal wetlands or may help to verify or augment national data sources.	Section 5.3 and Table 17: Global data sources for coastal wetlands

Key Messages	Section/Case Study
When applying global datasets it is recommended to ensure relevance and consistency of the product coverage (e.g., geographic extent and time) to national definitions and reporting requirements.	Section 5.3
Accuracy of global products for use at a national level is variable and needs to be assessed and documented when used for activity data.	Section 5.3
Measurement, reporting and verification	
Measurement, reporting and verification comprises a series of steps leading to greater transparency and comparability in NGGI reporting and mitigation actions as well as in individual, project-level (subnational) GHG mitigation efforts.	Section 6 and Box 15: TACCC principles - transparency accuracy, completeness, consistency and comparability
Uncertainty estimation	
It is good practice to focus on uncertainty reduction within identified key categories (and any subcategories), to support continuous improvement over time, and make best use of available resources.	Section 6.1 and Appendix B Fiji demonstration
There may be high uncertainty in carbon stocks in seagrasses and tidal marshes and thus higher reported uncertainties for these ecosystems can be expected in monitoring efforts over time.	Section 6.1
Completeness, time series consistency	
In the absence of national data for reporting key categories within coastal wetlands, it is good practice to include Tier 1 estimates using methods and default values from the 2013 Wetlands Supplement to meet the completeness principle of good practice in inventory compilation..	Section 6.2
Adopting the 2013 Wetlands Supplement to include coastal wetlands in NGGIs will trigger the requirement for the recalculation of results from previous inventory to maintain time series consistency.	Section 6.3
Coastal wetlands are likely to have national activity data gaps, making it challenging to develop a complete and consistent time series analysis. Expert judgement may be used in combination with limited data to develop a time series.	Section 6.3 and Box 16: How to address data gaps in and historical time series to initially incorporate Coastal Wetlands in National Greenhouse Gas Inventories

Key Messages	Section/Case Study
Quality assurance and quality control	
Countries may initially rely on default emission factors and globally available datasets to report on coastal wetland ecosystems and activities. In this case, quality control checks can be conducted.	Section 6.4 and Table 18: Useful quality control checks in applying default emission factors and global datasets applied in estimates within Coastal Wetlands
Reporting and documentation	
Following good practice guidance for reporting consistency can be complex with multiple reporting objectives and varying methodological requirements , however documentation assists to address communication of measurement, reporting and verification requirements.	Section 6.5 and Table 19: Recommended information and associated considerations to include with reporting
Reporting Coastal Wetlands in the Common Reporting Formats of the UNFCCC may result in estimates being reporting in Tables relating to all six land use classes.	Appendix B Fiji demonstration

2. Purpose and Context

2.1 Purpose

This document has been developed to provide practical advice[5] on incorporating coastal wetland ecosystems into NGGIs reported to the UNFCCC by consolidating Intergovernmental Panel on Climate Change (IPCC) guidance related to coastal wetland ecosystems.

Initially, guidance on coastal wetland ecosystems was not included in the 2006 IPCC Guidelines, with the exception of mangroves if they fell within national forest definitions The 2013 Wetlands Supplement addressed this gap, by providing guidance on the inclusion of coastal wetlands (mangroves, tidal marshes, and seagrasses) within national inventories (Chapter 4; IPCC, 2014). The 2013 Wetlands Supplement provided guidance for a limited number of activities within coastal wetlands (see **Section 4.2 Land-use categories**) and included guidance for estimating methane (CH_4) emissions for re-wetting (rehabilitation of mangroves and tidal marshes) and nitrous oxide (N_2O) emissions from aquaculture. Subsequently, guidance for estimating CH_4 emissions from wetlands was included in an Appendix to the 2006 IPCC Guidelines, and refined in the 2019 Wetlands Refinemen (Chapter 7; IPCC, 2019) to include estimating CH_4 emissions from aquaculture ponds, drains, ditches and canals, which are commonly found in drained coastal wetland ecosystems converted to agriculture, aquaculture or other land-uses.

The advice presented here aims to:

- Provide user-friendly advice for linking UNFCCC decisions related to coastal wetlands with existing IPCC guidance.
- Present detailed advice to support decision making and technical implementation related to reporting of GHG emissions and removals from related activities in coastal wetlands.
- Provide broad principles for the collection and use of data, which will remain relevant even as technologies and methods evolves.
- Illustrate how countries can apply the principles outlined in the document by using existing examples of national experience.

This document augments and links rather than repeats complementary advice presented in the Global Forest Observations Initiative (GFOI) Methods and Guidance Document (GFOI, 2020) such as:

- Processing of remotely sensed data.
- Establishing and augmenting a national field sampling frame.
- Integration of various sources of data.
- Treatment of multiple and historical land-use changes.
- Estimating and making use of emissions and removals uncertainty.

5 The term *guidance* is used in this document where there is a cross-reference to the IPCC guidance and advice is applied where complementary material is provided.

Blue carbon measurement protocols are outlined in the Blue Carbon Manual (BCI, 2019), including field sampling of vegetative and soil carbon pools in coastal ecosystems.

Policy advice for including blue carbon ecosystems into Nationally Determined Contributions (NDCs) and thus inventories have previously been presented in Herr et al. (2016) and Thomas et al. (2020). This document aims to provide methodological advice to report emissions and removals from coastal wetlands in NGGI, drawing largely from relevant IPCC guidelines and provides enriched methodological advice by giving country experiences of NGGI and REDD+ reporting relevant to coastal wetlands and Blue Carbon Initiatives.

The Australian Government is implementing blue carbon programs with Indonesia and the Pacific (focussing on Fiji and Papua New Guinea) to support incorporation of blue carbon in NGGIs, and climate policies. As partner countries in the blue carbon programs, Indonesia and Fiji were chosen to help the author group develop the advice and case studies from these countries are provided throughout the document to enhance its usability. A demonstration of how a country can apply this advice to develop a coastal wetlands national inventory, using publicly available data for Fiji, is provided in **Appendix B**. Practical training associated with this advice will support countries in developing their coastal wetlands inventories. Policy advice for blue carbon is being addressed under another component of the program.

2.2 Relevance to National Greenhouse Gas Inventory

Blue carbon ecosystems are covered as a land-use category under the UNFCCC GHG reporting guidance in the AFOLU category. Within the UNFCCC guidance, these ecosystems are generally referred to as ‘coastal wetlands” rather than using “blue carbon” terminology.

The 2006 IPCC Guidelines classifies all lands into broad land-use categories: Forest Land, Cropland, Grassland, Wetland, Settlement and Other Lands. The 2013 Wetlands Supplement, Chapter 4 on Coastal Wetlands, provides more detailed guidance on how to treat emissions and removals caused by human actions that affect coastal wetlands. Coastal wetlands in the 2013 Wetlands Supplement include mangrove forests, tidal marshes and seagrass meadows. Emissions factors and methodologies are provided for management actions that include:

Forest management practices in mangroves

- Extraction Rewetting, revegetation and creation of mangroves, tidal marshes and seagrass meadows
- Drainage in mangroves and tidal marshes

The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[6] (IPCC, 2019) updates the information in the 2013 Wetlands Supplement by providing new guidance for CO2 and non-CO2 emissions from Land Converted to Flooded Lands and Flooded Lands Remaining Flooded Lands, specifically to assess changes in the soil carbon pool. Such emissions may be important, particularly where coastal wetland areas are converted to aquaculture and agricultural lands.

The 2013 Wetlands Supplement and the 2019 Refinement follow the IPCC’s standard “tiered” guidance to GHG accounting.

Tier 1 includes default GHG emission factors (emissions and removals) for a range of activities.

6 Available from https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

These default factors allow a country to start accounting for emissions and removals on the basis of estimated land-use/land cover distribution data. Parties with greater resources (skilled people and money), can build more sophisticated assessments through subsequent Tier 2 and Tier 3 assessments, which requires country-specific data. These higher Tiers are typically used to develop estimates of categories (and subcategories) in a NGGI that contribute significantly to the overall estimate reported, otherwise known as key categories. Any decisions to move to Tier 2 and 3 should be made in the context of cost-effectiveness and key priorities (see **Section 3.5 Key category analysis**) for NGGI improvements across all sectors.

The Enhanced Transparency Framework of the Katowice Climate Package is centred on biannual reporting and technical expert reviews, common to all Parties, with flexibilities for least developed countries and small island developing states. By 31 December 2024 at the least, all Parties must move to reporting formats known as Biennial Transparency Reports (BTR) (**Figure 2**).

Developed countries were "encouraged" to use the 2013 Wetlands Supplement (for inventories submitted from 2015 and beyond) and hence to include coastal wetlands in their NGGIs and associated reporting. Under the new reporting requirements, the use of the 2006 IPCC Guidelines is required for all Parties (with flexibilities for least developed countries and small island developing states) and the use of the 2013 Wetlands Supplement is encouraged for all Parties.

Developing countries have the opportunity to self-determine their ability to meet all reporting requirements and make adjustments. They can use 'nationally appropriate methodologies" to prepare their inventory reports as long as they are consistent with the 2006 IPCC Guidelines (Thomas et al., 2020). Such decisions can be facilitated through formalising institutional arrangements (**Box 1**) through which collaboration can support decision making on which methodologies and indicators are applied.

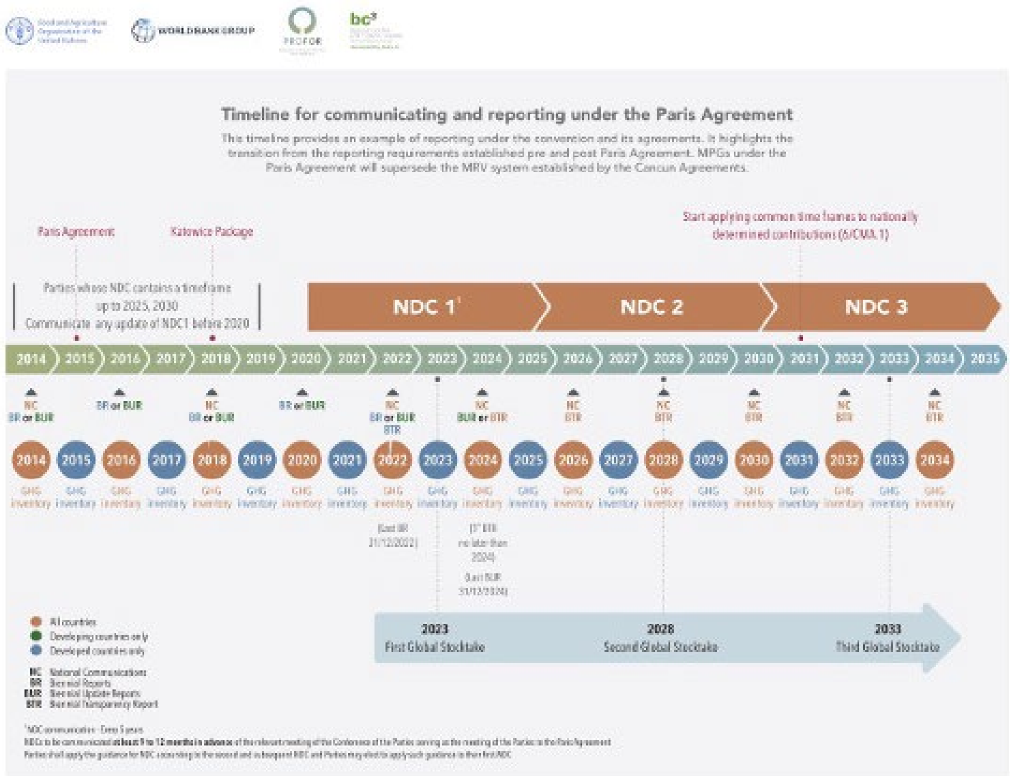


Figure 2: Reporting obligation and timelines for all Parties under the UNFCCC, pre and post the Paris Agreement (Sanz et al., 2020)

Within these institutional arrangements, developing steering committees or smaller working groups with a focus on specific technical issues can be an effective way of addressing data and capacity gaps. A number of REDD+ countries have experiences in establishing smaller multi-agency working groups with a focus on sharing resources rather than replication to fill national data gaps (GFOI, 2020). Such multi-agency working groups can serve as smaller more agile examples of operationalising the core concepts of institutional arrangements with a focus on specific issues within the group's expertise and responsibility.

Box 1: Formalising institutional arrangements in support of measurement, reporting and verification

Reporting any information at a national level requires a collaborative effort from a range of stakeholders such as government agencies, consultants and industry experts, research organisations, the private sector, and non-government organisations. Establishing institutional arrangements between stakeholders facilitates the production of quality, timely information by efficiently using resources and avoiding duplication of effort where possible. Institutional arrangements are most effective when built around the core concepts of (FAO, 2017; GFOI, 2020):

Foundational elements - including institutionalisation, developing national capacity, and external partnerships and collaboration.

Strategic elements - including defining mandates, identification of information needs and stakeholders, communication and dissemination, and effective use of resources.

Operational elements - including a framework for information management, system processes, infrastructure, documentation, and the supporting system qualities of quality assurance/quality control and continuous improvement.

Sound and effective institutional arrangements can be established through early and continuous stakeholder engagement combined with the documentation of roles and responsibilities and system, data quality, and delivery specifications. Combining stakeholder engagement and system documentation with continuous improvement review cycles can further assist in effective use of human and financial resources and leads to enhanced transparency and improved consistency and accuracy.

Some countries may have already established institutional arrangements for NGGI and/or REDD+ reporting within which the additional requirements for reporting coastal wetlands will reside. It is likely that some new relationships, data specifications or data sharing arrangements will need to be established with the inclusion of coastal wetlands in the NGGI (see Box 14) such as:

Seagrass extent indicators which may require discussions with agencies responsible for fisheries and national spatial data custodians that may not have provided data to the NGGI before.

Soil organic carbon stocks in various coastal wetland ecosystems may require collaborations between Ministries and research agencies to fill gaps in national datasets

2.3 Relevance to Forest Reference (Emission) Levels

Many developing countries with large areas of coastal wetland ecosystems, in particular mangroves, may have opted to voluntarily report emissions (e.g., deforestation/degradation) and removals (e.g., reforestation, regeneration) from mangrove areas to the UNFCCC (or other bilateral or multilateral programs) in the context of results-based payments. As such, these areas of mangroves have been defined as Forest Land according to a national forest definition and included in the REDD+ National Forest Reference Emission Level (FREL) / Forest Reference Level (FRL) (see **Box 2**).

Decision 12/CP.17 requires FREL/FRLs to maintain consistency with anthropogenic forest related emissions and removals in NGGIs, and decision 14/CP.19 requires consistency between emissions and removals reported for REDD+ activities and FREL/FRLs. Differing reporting objectives between NGGI and REDD+ reporting can add a layer of complexity in translating GHG emissions from REDD+ activities within mangrove ecosystems and maintaining consistency with the NGGI (**Table 2**).

Therefore, countries who have included mangrove areas in REDD+ FREL/FRLs should report these same mangrove lands under the Forest Land category in NGGI, opposed to the Wetland category. Tidal marshes and seagrasses would not meet the definitional thresholds of the national forest definition (**section 3.1**) and as such would be excluded from any REDD+ FREL/FRL reporting.

Box 2: Mangroves under Forest Reference Emission Level (FREL) in Indonesia

Indonesia considers all mangrove cover under the Forest Land category as reported under its FREL for deforestation and forest degradation (Ministry of Environment and Forestry, 2015). Indonesia submitted its first FREL to the UNFCCC in 2016 using the land cover change baseline data between 1990 and 2012 (Government of Indonesia, 2016). The latest BUR (Ministry of Environment and Forestry, 2018), reports 2.88 million ha of mangrove forests as of 2016, comprising 51% of primary and 49% of secondary forests. The primary mangrove forest comprises undisturbed intertidal mangrove trees and associates (e.g., *Nypa fruticans*), while secondary mangrove forest includes areas influenced by man-made disturbance (e.g., logging activities).

Consistent with other forest types, emissions were calculated from mangrove deforestation (conversion of primary and/or secondary mangrove forests into other land cover categories) and forest degradation (change of primary to secondary mangrove forests). Tier 2 values for the above-ground biomass carbon pool were used and compiled based on the available National Forest Inventory data (Krisnawati et al., 2015) as well as published field data (Donato, 2011; Murdiyarso, 2009). It was reported that above-ground biomass stocks for primary and secondary mangrove forests were 263.9 (209.0 - 318.8 95% CI, N=8) and 201.7 (134.5 - 244.0 95% CI, N=12) tonnes C ha^{-1}, respectively.

Activity data of mangrove deforestation and degradation were obtained through National Forest Monitoring System – an official repository system based on wall-to-wall land cover maps produced by using Landsat satellite imageries (http://webgis.menlhk.go.id/) (Ministry of Environment and Forestry, 2020) In the 2015 FREL, Indonesia reported historical forest cover changes based on land cover dataset produced for the year of 1990, 1996, 2000, 2003, 2006, 2009, and 2012. Given the current FREL in Indonesia only considers above-ground biomass, incorporation of other carbon pools, such as below-ground biomass, dead organic matter, and soil carbon can improve future emissions estimation from mangrove deforestation and degradation. Future inclusion of dead organic matter and soil carbon would be significant since both pools compose more than 80% of total carbon stocks (Murdiyarso et al., 2015) and represent key categories.

Table 2: Examples of reporting mangroves consistently between REDD+ activities and land-use changes in the Forest Land category of National Greenhouse Gas Inventories (NGGI)

Event/Activity	NGGI land-use category		REDD+ Compatible	Relevant IPCC Guideline
	Land use at time 1	Land use at time 2		
Mangroves are classified as Forest Land and undergo clearing, or drainage and converted to another land-use category.	Forest Land	Settlement; Cropland; Grassland; Wetland; Other land	Deforestation	2006 IPCC Guidelines Volume 4 AFOLU; 2013 Wetlands Supplement Chapter 4 Coastal Wetlands
Mangroves are classified as Forest Land and undergo selective harvesting or biomass clearing but still meet the national forest definition thresholds.	Forest Land	Forest Land	Forest degradation OR sustainable management of forests, enhancement of forest carbon stocks (within existing forest), and conservation of forest carbon stocks.	2006 IPCC Guidelines Volume 4 AFOLU
Coastal areas are afforested/reforested with mangrove species which meet the national forest definition thresholds.	Wetland	Forest Land	Enhancement of forest carbon stocks (afforestation of land not previously forest, reforestation of land previously converted from forest to another land-use)	2006 IPCC Guidelines Volume 4 AFOLU; 2013 Wetlands Supplement Chapter 4 Coastal Wetlands
Mangroves do not meet national forest definition threshold and are classified as Wetlands, and when subject to selective harvesting or biomass clearing remain reported as Wetlands.	Wetland	Wetland	Would not be included in REDD+ reporting	2013 Wetlands Supplement Chapter 4 Coastal Wetlands
Seagrass meadow or tidal marsh are converted into another land-use category	Wetland	Settlement; Wetland; Other land	Would not be included in REDD+ reporting	2013 Wetlands Supplement Chapter 4 Coastal Wetlands

The following lessons learnt from establishing FREL/FRL in the context of REDD+ are transferable to the development of national baselines[7] for coastal wetland ecosystems initiatives:

- Develop clear documentation and justification for inclusion/exclusion of nationall defined activities.
- If estimates are made for subnational areas, emission calculation methods used should either be consistent with those used in national inventories, or Parties should consider whether there is a need to achieve consistency, perhaps by increasing stratification in the GHG inventory.
- Activities are identifiable in the NGGI as IPCC categories, subcategories, or sums of categories or subcategories.
- Averaging a historical time series to establish representative historical levels of emissions and removals can have significant limitations under circumstances where historical emissions/removals don't reflect likely future emissions, especially where reforestation or enhancement activities represent a large component of the FREL/FRL.
- Consideration of variation within the historical period can assist with analysis of emission/ removal drivers or effectiveness of policy interventions.
- Although the UNFCCC does not specify a period, 10 to 15 years could be considered a feasible and useful period for time series making sure to consider the number of estimates during this time period as it is not possible to understand trends where only two or three time-points are available over a 10 to 15 year period (GFOI, 2020).
- A stepwise approach as a way to incorporate better data or methodologies may entail improvements to the NGGI, as well as to the FREL/FRL estimates to maintain mutual consistency (see Box 3).
- Work completed for mapping of forest cover can create opportunities for collaboration and data sharing between government agencies responsible for land managemen (e.g., Ministries of Forestry, Ministries of Fisheries, Ministries of Environment) to work together in mapping mangrove as blue carbon, instead of duplicating work.

7 The term baseline is generally used in the context of projects, while a reference emissions level (REL) refers to a similar idea under national accounting approaches, such as those envisioned to generate compensated emission reductions under REDD+.

Box 3: The stepwise inclusion of mangrove ecosystems in Fiji's Forest Reference Emissions Level (FREL) / Forest Reference Level (FRL)

Fiji monitors changes in the extent of mangroves as part of its national land classification program using wall-to-wall remotely sensed data. A lack of Tier 2 mangrove data to estimate emissions and removals from key carbon pools including above-ground and below-ground biomass and soil organic carbon led to the exclusion of mangrove ecosystems from the country's subnational FREL/FRL submitted to the Forest Carbon Partnership Facility (FCPF). As an interim measure, Fiji will report annual areas of change in mangroves (i.e., activity data related to mangroves but not emissions reductions) to the FCPF Carbon Fund. In the context of stepwise improvement and inclusion of key categories, Fiji has designed a new National Forest Inventory (NFI) program which incorporates the collection of data from mangrove ecosystems which will be combined with national specific allometric equations to enable estimates of carbon stock change to be made in above-ground and below-ground biomass. Soil organic carbon measurements are also being made as part of the NFI and will contribute to establishing carbon stock data for this important pool. It is intended that this data will enable the stepwise continuous improvement of the FREL/FRL to enable reporting of emissions and removals from mangrove ecosystems.

Remaining gaps in national data following the first round of NFI measurements include emission factors for mangrove restoration/rehabilitation. These gaps will be considered in the context of key category analysis for prioritisation in Fiji's National Forest Monitoring System continuous improvement plan. In addition, future research and exploration for emission/removal assessments and mapping for seagrass and tidal marsh are among the national data gap considerations related to reporting of coastal wetlands in Fiji's NGGI.

2.4 Relevance to broad policy objectives

Beyond NGGIs and the inclusion of mangroves in REDD+, countries may wish to monitor, measure and report GHG emissions from coastal wetland ecosystems in support of broader synergistic national policy objectives and build awareness of the importance of managing blue carbon ecosystems, climate response planning (adaptation) and biodiversity conservation.

Monitoring of spatial extent and temporal change combined with available emission factors can facilitate reporting under a range of international conventions and goals, such as those in **Table 3: Relevant United Nations conventions and other non-legally binding reporting relevant to coastal wetlands**. Some examples and experiences of countries addressing multiple reporting objectives are presented in **Table 4** and **Box 4**.

Table 3: Relevant United Nations conventions and other non-legally binding reporting relevant to coastal wetlands

Reporting Mechanism	Description	Type1
Nationally Determined Contributions **(NDCs)**	Whilst blue carbon ecosystems are not explicitly described in the text of the Katowice Climate Change Package (i.e., the Paris Rulebook), the carbon sequestration and storage potential of these important sinks and sources are implicitly included as part of the guidance. Coastal wetland ecosystems can be included in NDCs to achieve both climate change mitigation and adaptation targets and goals.	Convention
Ramsar Convention on Wetlands of International Importance	Ramsar resolution (XIII.14) promotes the conservation, restoration, and sustainable management of coastal wetlands, including encouraging Parties to update their NGGIs to better reflect data for wetlands including carbon storage and fluxes in Ramsar coastal wetland sites.	Convention
Convention on Biological Diversity	The Convention on Biological Diversity is dedicated to promoting sustainable development recognising that biological diversity is about more than plants, animals and micro-organisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live. National reports present the status of progress towards meeting our national and global targets which should include these important coastal wetland ecosystems.	Convention
Sustainable Development Goals (SDGs)	Protecting and restoring coastal wetland ecosystems are a key link to achieving the United Nations SDGs which have been developed as a means to overcome poverty and foster social and economic development. SDG 14 - Life Below Water aims to reverse the current trend of the degradation of marine and coastal habitats and maintaining the amount of carbon sequestration, significantly increase the area of coastal wetland ecosystems under effective ecosystem-based management, and mobilise finance for protecting and rehabilitating coastal and marine habitats, thus enhancing their capacity for carbon storage and sequestration providing a further link to SDG 13: Climate Action.	Non legally binding

Reporting Mechanism	Description	Type1
United Nations Decade on Ecosystem Restoration (2021–2030)	During the United Nations General Assembly in March 2019, a resolution A/RES/73/284 on the Decade on Ecosystem Restoration (2021-2030) was adopted. This platform is led by the United Nations Environment Programme and the Food and Agriculture Organisation and is aimed to provide a hub for accelerating global ecosystem restoration initiative in the next decade. Coastal wetlands are among identified key ecosystems for the restoration targets, specifically to optimize their roles in blue carbon storage and sea-level rise adaptation.	Non-legally binding
United Nations Decade of Ocean Science for Sustainable Development (2021-2030)	This initiative was mandated by the United Nations General Assembly. The Intergovernmental Oceanographic Commission of UNESCO coordinate the Decade's preparatory process which is aimed at supporting efforts to reverse the cycle of decline in ocean health and gather ocean stakeholders worldwide behind a common framework that will ensure ocean science can fully support countries in creating improved conditions for sustainable development of the ocean. This initiative has strong links to the SDGs.	Non-legally binding
Marine Protected Areas (MPAs)	MPAs are a policy instrument available to address conservation of coasts and marine areas. SDG 14 promotes an increase in the global coverage of MPAs These designations, existing policies and reports (e.g., UNESCO World Heritage sites) can be useful to incorporate into climate change mitigation and/or adaptation actions.	Non-legally binding

1 A convention is a legally binding agreement between states of the United Nations.

Box 4: Mangrove Ecosystems for Climate Change Adaptation and Livelihoods (MESCAL) project, Fiji

The MESCAL project was implemented by IUCN Oceania to increase the resilience of Pacific Island people to climate change through mangrove management. It was undertaken in five partner countries, including in collaboration with the Government of Fiji, where it: 1) reviewed the extent to which mangroves, their use and management are considered in existing Fiji national policies and legislation (IUCN), 2) assessed carbon stocks of intact mangroves in Rewa Delta, and 3) assessed emissions from mangrove conversion to agriculture or infrastructure development (Heider, 2013). The purpose of project was to initiate the development of a baseline for national level emissions and quantify the role of mangroves in the REDD+ strategy. It also involved technical training of Government stakeholders in mangrove long plot surveys, shoreline video assessments, fisheries surveys, and carbon assessments, and a National Mangrove Media Awareness Campaign (partnering with WWF, Ministry of Lands, Department of Environment).

In Fiji, mangroves are addressed across a number of different policies, such as the National Biodiversity Strategic Action Plan, Integrated Coastal Management Framework, Forest Policy, Tourism Development Plan, and recently the Low Emissions Development Strategy (LEDS). The Mangroves Management Plan 2013 was developed to respond to the lack of specific policy for mangroves, however, has not been formally adopted by the Government of Fiji. The responsibility of mangrove management is shared amongst various government departments, including the Ministry of Forestry, Ministry of Economy, Ministry of Fisheries, and Ministry of Environment. A Mangrove Management Committee was established in 1983 to advise the Lands and Survey Department on matters concerning mangroves in Fiji and aims to bring together the various bodies that influence mangrove management to promote sustainable use. Given the involvement of a number of government departments in the regulation of coastal wetland ecosystems in Fiji, there are challenges with including coastal wetlands into NGGI which include data sharing, unclear governance arrangements, and interagency communication. The Fiji LEDS is Fiji's key strategy to mitigate climate change and builds on existing mitigation and adaptation actions that are being undertaken under Fiji's Nationally Determined Contribution reported to the UNFCCC (Ministry of Economy, 2018). A key focus of the Government of Fiji (and many other small island developing states) is on reducing emissions and adapting to climate change, therefore inclusion of coastal wetlands into the NGGI can be linked to LEDS (or other climate strategies), to enable development of the institutional arrangements required to facilitate this work (e.g., data sharing agreements, roles and responsibilities of government departments).

Table 4: National policy examples from Fiji and Indonesia and their relevancy to global policy objectives

Country	Case of GHG inventory	Policy relevancy for blue carbon ecosystems	Relevant national stakeholders	Relevant global policies
Fiji	Low Emissions Development Strategy (LEDS)	While not directly incorporated into the net total emissions (or net negative) projections for the different scenarios, the LEDS also considers emission scenarios resulting from efforts to protect and restore coastal wetlands, which have the potential to sequester significant amounts of carbon dioxide. In conserving coastal wetlands, it will be critical for Fiji to adopt a mangrove management plan, to develop and implement policies and plans to replant mangroves, and to conduct extensive mapping and establish field studies of mangroves as well as seagrasses. The inclusion of mangroves and other coastal wetlands in future updates to Fiji's LEDS could add significantly to the potential to achieve deep decarbonisation in Fiji's economy.	Ministry of Forestry, Ministry of Fisheries, Ministry of Environment and Waterways	Sustainable Development Goal 13; United Nations Decade of Ocean Science for Sustainable Development
	Emissions Reduction Program Document	Fiji submitted its Emission Reduction Program Document to the Forest Carbon Partnership Facility (FCPF) and was accepted into the Carbon Fund. Whilst not included in Fiji's Forest Reference Emission Level (FREL), mangrove areas are mapped in Fiji's national forest / non forest cover mapping and any areas of change within mangrove ecosystems will be reported in regular monitoring reports to the FCPF Carbon Fund. National data collection programs are being established to enable the stepwise inclusion of mangroves into the national FREL in the future.	Ministry of Forestry, Ministry of Fisheries, Ministry of Economy	REDD+; National Determined Contributions

Country	Case of GHG inventory	Policy relevancy for blue carbon ecosystems	Relevant national stakeholders	Relevant global policies
Indonesia	Forest Reference and Emission Level (FREL)	Indonesia submitted their first FREL in 2015 to the UNFCCC as part of the REDD+ results-based payment scheme. While FREL only considers emissions and removals from Forest Land, Indonesia categorises mangrove into Forest Land rather than Wetland. Consequently, Indonesia's first FREL reported mangrove emissions/removals using emission factors from above-ground biomass carbon pool from primary and secondary mangrove forests and activity data from spatial-based annual mangrove deforestation rates. Inclusion of other carbon pools and recognition of land-use change, which replaced deforested mangrove forests, can improve future FREL.	Directorate General of Climate Change, Ministry of Environment and Forestry is the national focal point to the UNFCCC	REDD+; National Determined Contributions
	Low Carbon Development Initiative (LCDI)	The LCDI was established in 2017 and integrated into the mid-term national development plan of 2020-2024 through Presidential decree number 18 2020, and is administered by the Ministry of National Development Planning (Bappenas). It is a national development platform for the incorporation of economic and social growth sustainability through low GHG emissions activities. LCDI approaches are relevant to the Sustainable Development Goals, specifically to support climate action at national scale (SDG 13). LCDI is formalised under Midterm National Development Plan 2020-2024, specifically to support and promote green economy across national development activities.	Ministry of National Development Planning (Bappenas) Ministry of Marine Affairs and Fisheries	Sustainable Development Goal 13; United Nations Decade on Ecosystem Restoration; Ramsar Convention; United Nations Decade of Ocean Science for Sustainable Development

Country	Case of GHG inventory	Policy relevancy for blue carbon ecosystems	Relevant national stakeholders	Relevant global policies
Indonesia	Low Carbon Development Initiative (LCDI)	Mangroves and seagrasses are specifically incorporated in the LCDI. One of the main implementations is focused on restoring degraded mangroves. The expected outcomes include economic benefits (e.g., ecotourism, fisheries), environmental benefits (carbon stocks enhancement), and social benefits (safeguarding coastal communities and their livelihoods). With the Ministry of Marine Affairs and Fisheries, LCDI also assess GHG emissions baseline and mitigation projection scenarios from mangrove conservation and restoration. This assessment involves subnational stakeholders and therefore promoting NGGI for coastal wetland ecosystems at the local jurisdictional level. LCDI demonstrates the importance of data and methodological sharing, strengthening relationships between national and regional agencies in the context of NGGI for coastal wetland ecosystems in Indonesia.	Ministry of National Development Planning (Bappenas) Ministry of Marine Affairs and Fisheries	Sustainable Development Goal 13; United Nations Decade on Ecosystem Restoration; Ramsar Convention; United Nations Decade of Ocean Science for Sustainable Development

3. Design decisions

This chapter describes methodological-related and policy-related design decisions relevant to the establishment of an operational NGGI process that incorporates coastal wetland ecosystems, taking into consideration the benefits of multipurpose monitoring (Chapter 2) of these important ecosystems.

The design decisions are presented around the core concepts of:

- Including coastal wetland ecosystems in the national policy dialogue. This can support the development of national and subnational policies, cooperation between governments and intra-government agencies and inclusion of the private sector and community groups.
- Applying the 2013 Wetlands Supplement and include coastal wetland ecosystems in NGGI and National Communications. Improved quantification of emissions and removals due to land management can enable setting of goals and benchmarks for Nationally Determined Contributions to international climate mitigation targets as set out i the Paris Agreement.
- Reporting trends of coastal wetland ecosystems, including improved mapping of areas, changes through time, threats and status. Monitoring landscape changes supports responses to drivers of change and management planning for ecosystem protection and restoration.

To address these core concepts a number of steps, or key design decisions, are important to consider. For each design decision, methodological options are described that countries can adopt. These design decisions are not consecutive steps but rather dependent considerations when designing the national inclusion of coastal wetland (or land sector) emissions/removals in NGGIs. The design elements discussed in this section are:

- Land representation - defining coastal land, noting good practice for consistent representation of lands.
- Stratification – allocation of lands to various strata can reduce uncertainty and improve efficiencies in producing emissions/removals estimates.
- Changes and disturbances - quantification of land-use and land-use change within defined coastal wetland ecosystems is a starting point for generating activity data.
- Attribution - allocating the drivers of land-use change to various strata can assist in aligning appropriate methodologies and emission factors to generate emissions/removals estimates.
- Relevant carbon pools and gases - selection and application of appropriate emission factors to various defined strata to meet reporting objectives.
- Methods, approaches and tiers - the adoption of a specific method, approach and tiers is driven by a combination of the purpose of the inventory and data availability. These IPCC concepts are not fixed once first applied and many countries adapt and change through time.
- Key category analysis - taking progressive steps to improve estimates through time is an effective way to develop processes for including all sectors and categories in NGGI, whilst working towards higher tier methods for those that lead to significant emissions/removals.

3.1 Land representation

Coastal land is land at or near the coast on which coastal wetlands occur. It is good practice that a country clearly defines the concept of 'coastal land' and its seaward limits (e.g., distance from the coast, bathymetric contour or vegetation distribution) and landward limits (e.g., distance from the coast, elevation contour or vegetation distribution) in accordance with its national circumstances and applies that definition consistently both across the entire national land area and over time. Some definitions that have been used are:

- IPCC Working Group II defines coastal systems as "conceptualised to consist of both natural and human systems. The natural systems include distinct coastal features and ecosystems such as rocky coasts, beaches, barriers and sand dunes, estuaries and lagoons, deltas, river mouths, wetlands, and coral reefs. These elements help define the seaward and landward boundaries of the coast. The human systems include the built environment (e.g., settlements, water, drainage, as well as transportation infrastructure and networks), human activities (e.g., tourism, aquaculture, fisheries), as well as formal and informal institutions that organize human activities (e.g., policies, laws, customs, norms, and culture)".
- 2013 Wetlands Supplement indicates that the "boundary of coastal wetlands may extend to the landward extent of tidal inundation (to the highest astronomical tide; HAT) and may extend seaward to the maximum depth of vascular plant vegetation".
- The Ramsar definition of wetland is broader and includes "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres"(Ramsar Convention, 2018).
- All land that is not coastal is inland.

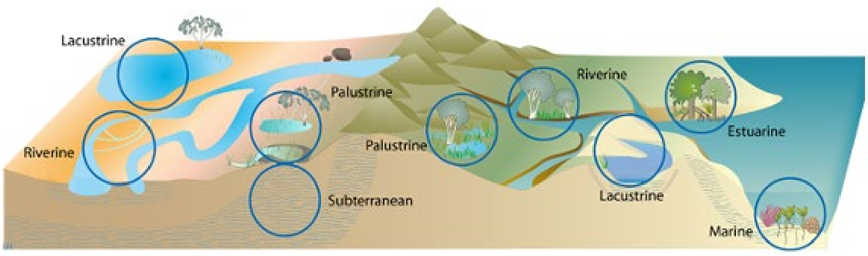
Important considerations: An anticipated question arises as how to set the extent of tidal boundaries for the coastal regions that do not have tide data. In many coastal settings tidal boundaries are unclear. Mangroves may grade gradually into raised dome coastal peatlands that are not submerged by tides, but rivers are tidal. Coastal wetlands may grade gradually into river wetlands, and in low tidal systems for times of the year the whole wetland may be dominated by river flows. It is known that it can be difficult to define boundaries, in particular mangroves to peatlands. In these cases, it is good practice to report uncertainty around under- or over-estimates in land transitions. What is most important for NGGI reporting is not how a country defines these areas but rather that any definition or method applied to delineate these areas, and the change in these areas, is applied consistently through time.

In essence, the setting of boundaries to the coastal land area is an approach to aid estimating and reporting emissions and removals and countries have wide ranging discretion on how and where to set these boundaries. A country may elect, for example, to define the landward extent of the coastal land area as the historic boundary of mangrove forest and tidal marshes. This would define a region that mangroves continue to, and once existed if converted to other land-uses, and reflects the lands where mangroves may be reforested in the future.

The seaward boundary of vegetated intertidal wetlands is readily mapped by remote sensing, and this extent may already represent the seaward boundary of the national land representation. Countries may elect to extend this boundary to include seagrass areas or even as far as another consistent feature (e.g., a bathymetric depth contour or the extent of the Exclusive Economic Zone). To date, however, addressing the inclusion of seagrasses is experimental and there is no clear guidance on best practice as yet.

A range of wetland classification systems are used globally to support management of wetlands, including coastal wetlands, such as the Ramsar classification system (Ramsar Convention, 2012), the Coastal and Marine Ecological Classification Standard (Federal Geographic Data Committee, 2012), and the new IUCN Global Ecosystem Typology (Keith, 2020). It is good practice to adopt a consistent national classification framework for classifying and reporting on the area of different coastal wetland types and their change over time. An example of a typical wetland classification system is in Box 5.

Box 5: Queensland Government Wetland Classification System (Department of Environment and Science, 2013)



Riverine wetlands are all wetlands and deepwater habitats within a channel. The channels are naturally or artificially created, periodically or continuously contain moving water, or connecting two bodies of standing water.

Einasleigh River
Photo by Cathy Ellis

Lacustrine wetlands are large, open, water-dominated systems (for example, lakes) larger than 8ha. This definition also applies to modified systems (for example, dams), which are similar to lacustrine systems (for example, deep, standing or slow-moving waters).

Chinchilla Weir
Photo by Cathy Ellis

Palustrine wetlands are primarily vegetated non-channel environments of less than 8 hectares. They include billabongs, swamps, bogs, springs, soaks etc, and have more than 30% emergent vegetation.

100 Mile Swamp
Photo by Cathy Ellis

Marine wetlands include the area of ocean from the coastline or estuary, extending to the jurisdictional limits of Queensland waters (3 nautical mile limit). This definition differs from that in Ramsar, as it includes waters deeper than 6m below the lowest astronomical tide.

Cape Bedford Photo
Photo by Nick Cuff

Estuarine wetlands are those with oceanic water sometimes diluted with freshwater run-off from the land.

Mangrove
Photo by Cathy Ellis

Subterranean wetlands are wetlands occurring below the surface of the ground and that are fed by groundwater i.e. caves and aquifers. These wetlands provide water to groundwater dependent ecosystems.

Photo by Moya Tomlinson

Information that may assist in representing coastal wetlands in NGGI include:

- **Maps of different vegetation types and flooded land from inventory or remotely sensed data**[8]. Different plant species and communities of differing above-ground biomass (see 2013 Wetlands Supplement, Annex 4A.2 and 4A.3) occupy different regions of the coastal land depending on their tolerance of salinity and inundation. For example, often the largest mangroves occur in river deltas with high rainfall which are regularly inundated, while mangroves further from the water (often with reduced tidal inundation) can form extensive scrub communities that have trees less than 2 m tall (**Figure 2** and **Figure 3**)[9]. Some coastal wetlands can occur further inland or at higher elevation than the level of the HAT if tides influence the height of the groundwater table or if storm surge imposes a marine influence or seasonal flooding occurs (e.g., palustrine and estuarine wetlands). Other coastal wetlands, for example, those in brackish or flooded freshwater settings, which are dominated by flooding tolerant tree types (e.g., trees of *Melalueca, Pandanas, Casuarina*) often occur on coastal floodplains landward of mangroves and tidal marshes and could be included as Forest Land.
- Maps of soil types. Coastal wetlands occur on both organic and mineral soils which can influence emissions and removals (see 2013 Wetlands Supplement, Table 4.11). Tier 1 emission factors for rewetting and drainage (2013 Wetlands Supplement, Table 4.12 and Table 4.13 respectively) are aggregated for mineral and organic soils. Global assessment of mangrove soil carbon are available in Section 5.3 Global data sources.
- Maps of elevation relative to mean sea level (MSL). Mangroves and tidal marshes usually occur from approximately MSL to the level of the HAT. Seagrass meadows occur below MSL to varying depths that are determined by light penetration to the sea floor, which is influenced by turbidity of the water[10].

The approach adopted to map the spatial extent of coastal wetlands should be consistent through time, transparent (document data sources used), and use metric units.

8 See Section Data sources for discussion of limitations

9 See Section 5 Data sources for links to global data layers of mangrove height and biomass.

10 Global extent of coastal wetlands are available in Section 5.3 Global data sources.

Figure 3: Mangrove scrub in northern Australia (Image: Credit: Ilka C. Feller, Smithsonian Institution)

Figure 4: Mangrove scrub in Fiji (Image: C. Cameron)

Coastal wetlands and their alternative land-uses are included within AFOLU categories. These include:

- Forest Land - mangroves may fall within this category if they meet, or are expected to meet, the countries definition of Forest Land[11]. In some cases, mangroves will not meet the definition of Forest Land because of small stature of above-ground biomass (do not reach maximum height or canopy cover thresholds of forest definitions) and could be included in Wetlands. Even if the above-ground biomass is low soil carbon stocks may be large.
- Wetlands - Coastal Wetlands may be included within Wetlands. The IPCC provides guidance for inventories for coastal wetlands (mangroves, tidal marshes and seagrass meadows), inland wetlands, constructed wetlands, seasonally flooded agricultural land including intensively managed or grazed wet meadow or pasture, salt exploitation sites, excavated peatlands and wastewater treatment area (2013 Wetlands Supplement, Chapters 3, 4, and 5), as well as for additional human-made and managed flooded land categories, e.g. ponds, canals and drainage channels or ditches and aquaculture ponds (2019 Wetlands Refinement, other constructed water bodies). A summary of IPCC guidance for management activities in coastal wetlands (Table 6) and human-made and managed flooded lands (Table 7) are available in Section 4 Coastal wetlands methodological considerations.

Examples of management activities that may result in change in land-use category for Coastal Wetlands are identified below and scenarios are represented in **Section 4.3**:

- Mangroves can be managed for extraction of timber and fuelwood or converted to alternative land-uses (e.g. Forest Land to Grasslands for grazing) and thus they can be in various states of recovery to their original biomass (2013 Wetlands Supplement, Section 4.2.1).
- Mangroves converted to aquaculture ponds could be Forest Land to Wetlands (Flooded Land), or if mangroves are included in the Wetlands category, Wetlands remaining Wetlands. At Tier 1, emissions from loss of mangrove biomass and excavation of soil carbon can be estimated (2013 Wetlands Supplement, Section 4.22), and for aquaculture use nitrous oxide (2013 Wetlands Supplement, Table 5.15) and methane emissions (2019 Wetlands Refinement, Table 7.12) can be estimated.
- Mangroves and tidal marshes can be converted to croplands (Forest Land to Cropland or Wetland to Cropland), particularly for rice, oil palm, sugarcane or other crops that grow on coastal floodplains. At Tier 1 emissions associated with loss of mangrove biomass and from drainage of land can be estimated (2013 Wetlands Supplement, Table 4.13).
- Tidal marsh and seagrass converted to aquaculture are considered Wetlands remaining Wetlands (Flooded Land). At Tier 1 emissions from loss of soil carbon resulting from excavation can be estimated and for aquaculture use nitrous oxide (2013 Wetlands Supplement, Table 5.15) and methane emissions (2019 Wetlands Refinement, Table 7.12) can be estimated.

11 The IPCC therefore anticipates countries will have a forest definition with quantitative thresholds, based on land use, since temporary loss of forest cover does not entail transition to another land use, provided there is expectation of recovery of threshold values. Threshold values commonly refer to minimum area (e.g., between 0.05-1.0 hectare), percentage crown cover (e.g., 10-30 %) and tree height at maturity (e.g., 2-5 m), although other thresholds are possible (e.g., referring to minimum width).

- Coastal Wetlands can be converted to Grassland if they are modified to support grazing (Wetlands (e.g., tidal marsh) to Grassland). At Tier 1 emissions loss of mangrove above-ground biomass and from drainage of land can be estimated (2013 Wetland Supplement, Table 4.13).
- Coastal Wetlands can be converted to Settlements (e.g., seagrass is filled and converted to Settlement). At Tier 1 emissions can be estimated for loss of biomass and soil carbon (2013 Wetlands Supplement, Section 4.22).
- Coastal Wetlands can be converted to Other Lands (e.g., bare soil, unvegetated flooded lands, rock, ice, and all unmanaged land areas). For example, with dredging or due to poor water quality, seagrass can be converted to unvegetated flooded land, or tidal marshes can be converted to unvegetated open water wetlands as a result of erosion, e.g. see Box 6 (Australian seagrass example) and Box 10 (United States GHG inventory example).
- Management activities to rehabilitate or restore coastal wetlands can result in conversion of Cropland, Grassland, Settlements, Other Lands or Other Wetlands to Forest Lands (mangrove forests), Wetlands or Flooded Lands. For example:
  - Grasslands - At Tier 1 emissions or removals can be estimated when Grassland transition to coastal wetlands with rewetting associated with coastal wetland restoration or rehabilitation, e.g., Grassland to Forest Land or Grassland to Wetlands (2013 Wetlands Supplement, for CO_2 Table 4.13 and for CH_4 Table 4.14).
  - Cropland - At Tier 1 cropland can transition back to coastal wetlands with rewetting (e.g., rice Cropland to Wetlands (2013 Wetlands Supplement, for CO_2 Table 4.13 and for CH_4 Table 4.14).
  - Aquaculture ponds converted to mangroves – At Tier 1, removals can be estimated when Wetlands (Flooded Land) are converted to Wetlands or Forest Land with revegetation (2013 Wetlands Supplement, Table 4.2 and 4.3 for above-ground biomass, and Table 4.12 for soils) (**Figure 7**).

Box 6: Experimenting with incorporating seagrass in national greenhouse gas inventory in Australia

Australia's inventory team are working to incorporate seagrass in the NGGI with a focus on estimating emissions from seagrass associated with dredging. Initially, a 6 m depth contour was used to define the land area, which is the depth limit of the Ramsar wetland definition. This approach was discarded as dredging (and seagrass) can occur deeper than 6 m. Instead, the limit of the seagrass vegetation itself was used to define the land area over which emissions from dredging were estimated, based on the 2013 Wetlands Supplement that recommends that "the boundary of coastal wetlands may extend to the landward extent of tidal inundation and may extend seaward to the maximum depth of vascular plant vegetation." Dredged seagrass land (vegetation removed) was allocated to the Wetlands Converted to Other Land category (pers. comm. Australian Government, December 2020).

3.2 Stratification

Stratification is the process of disaggregating a land-use category/subcategory (e.g. Coastal Wetlands) into logical, typically homogeneous, sub-divisions (e.g. activity types, mangrove ecosystems) (see Box 7). Uncertainties can be reduced through stratification by significant factors responsible for within-country differences in land-use and management impacts, such as variation among climate domains and/or organic soil types. The strata size and number should aim to balance desired accuracy, required time, and available resources in the context of NGGI by:

- Estimating emissions and removals for key land-use subcategories.
- Applying the defined stratification consistently across the entire time series.
- Enabling the tailoring of specific methods or data collection processes in different strata (e.g., Tier 2 methods and national data for key categories opposed to Tier 1 methods and default data for non-key categories).
- Tracking areas under conversion across time-series, especially to deal with subsequent changes to avoid double counting of emissions and removals from a single category that is impacted by more than one activity[12].
- Assisting in the management of uncertainties and plan continuous improvement of the inventory.
- Increasing the flexibility in reporting of monitored data, such as the effectiveness of policies tailored to specific strata.

Applying strict stratification criteria that results in many small strata (that all need to be sampled) or conversely using loose criteria that create only a couple of large strata (where some variation will be missed) can negate any advantage from stratification. It is recommended that stratification be carried out such that the criteria used to define the strata are related to the variable being measured (GFOI, 2020). In the context of coastal wetland ecosystems this could be related to ecosystems, carbon pools, or specific activities.

Carbon dioxide and methane emissions are often a function of present vegetation composition and previous land-use history, therefore stratification of an area by these properties can improve emissions estimates. Some factors to consider when defining strata to improve emissions estimates in coastal wetland ecosystems include:

- Historical land-use (drainage and other management systems).
- Existing land-use (tidal marsh areas being used for agricultural purposes).
- Potential land-use (areas vulnerable to conversion for aquaculture or development or ideal for reestablishment/regeneration).
- Variation in soil characteristics (soil depth or type, or sediment grain-size).
- Variation in vegetation characteristics (BCI, 2019).

12 Where the stratification is based on land-use and is updated for each inventory, changes in land-use between measurement periods can complicate the estimation of changes in carbon stocks over time. As such, the 2019 Refinement notes it is good practice to use stratification methods that do not lead to bias or time-series inconsistencies due to changes in land-use.

Stratification of land-use categories according to climate domains, based on default or country-specific classifications, can be accomplished with overlays of land-use on suitable climate and soil maps. Tier 2 approaches are likely to involve a more detailed stratification of management systems, under the respective land-use category compared to Tier 1 approaches if sufficient data are available. For example, because tidal marshes can occur in a range of climates, disaggregating by climate may improve estimates if those country-specific data are available.

Stratification can also support transparency among activity reporting and NGGI estimates when the activity does not correspond to an entire NGGI category such as applying the coastal wetland methodology in the 2013 Wetlands Supplement.

Finally, the addition of coastal wetland ecosystems in a NGGI is likely to require changes to national land classifications. When changes to the stratification system occur, countries should maintain time series consistency (Section 6.3) by recalculating the entire time series of estimates using the new stratification (GFOI, 2020).

Box 7: Stratification choices for coastal wetlands

Being located in between land and marine environments, coastal wetland ecosystems are naturally stratified in different ways depending on geographical location, climate conditions, floristic and species composition, and level of tidal inundation. The 2013 Wetlands Supplement classifies mangroves and provides their default emissions factor for tropical wet, tropical dry, and subtropical regions reflecting differences in their above-ground biomass. Researchers also define the mangrove region following their distinct floristic and species composition (Duke et al., 1998). For example, Indo-West Pacific region covering many countries including Indonesia, Papua New Guinea, Australia and Fiji has a similar diverse mangrove species composition compared to the Atlantic-East Pacific region that has much lower mangrove species diversity. In addition, the variation of hydrology and geomorphology characteristics between coastal landscapes can influence carbon stocks. For example, mangrove landscapes in deltaic and estuarine settings commonly occupy extensive areas on coastal floodplains storing larger carbon stocks compared to mangroves located in oceanic settings or lagoons. Some examples of coastal wetland ecosystem stratification are presented in Table 5. Mapping mangroves by vegetation structure (for example by geomorphic and biophysical classifications in the Fiji demonstration in Appendix B) can allow the separation of mangrove forests (and all carbon pools) to Forest Land and mangrove shrubs to Wetlands.

Table 5: Examples of stratifying coastal wetlands

Ecosystem	Country	Stratification	References
Mangrove	Indonesia	For NGGI purposes, natural mangrove forests in Indonesia are categorised into primary and secondary forests. Primary mangrove forests are defined as undisturbed mangroves, while secondary mangrove forests are degraded through extraction or other activities. This is not to be confused with the national mangrove map, which categorises mangroves based on the canopy cover (dense, medium, sparse) for the purposes of determining the extent of mangrove forest.	Indonesian FREL and biennial update report (Ministry of Environment and Forestry, 2015, 2018)
	Fiji	Mangrove stratification follows a distinct variation of natural species composition and forest structure, including tall *Bruguiera, Rhizophora* and scrub mangroves.	Cameron et al. (2021); Tuiwawa and Tuiwawa (2012)
	United States	Mangroves are reported under Forest Land if they meet the definition of forest. Where these ecosystems do not meet the forest definition, they are considered scrub mangroves and reported as Wetland/Coastal Wetland.	Crooks et al. (2018)
	Global	Tropical Wet, Tropical Dry, and Subtropical Floristic and biogeographic region Hydrogeomorphological characteristics	Duke et al. (1998); IPCC (2014); Woodroffe (1992); Worthington, zu Ermgassen, et al. (2020)
Seagrass meadow		Minerogenic and organic sediments	see **Section 3.1 Land representation**
Tidal marsh	United States	Estuarine (saline) or Palustrine (freshwater)	Environmental Protection Agency (2020)

3.3 Changes and disturbances

Land-use changes and disturbances represent activity data in the AFOLU sector of NGGIs. Monitoring land-use changes and disturbances traditionally involved monitoring the land surface between two time periods, either using sample data or sample data combined with maps. GFOI (2020) provides detailed explanations of how to best utilise remotely sensed observations to generate activity data and suggest that in general, the two most important characteristics to change detection for the purposes of monitoring land-use change are time series and attribution.

3.3.1 Time series

The term time series in a remote sensing context typically refers to a time series of observations of the same location acquired from a remote sensing instrument. Time series-based approaches have many advantages, as they are not so dependent on the conditions at the time the individual images were collected (GFOI, 2020). Analysis of time series data enables the monitoring of more subtle changes in ecosystem health and condition related to land-use dynamics, and hence, shifts the analysis away from traditional change detection using two points in time, to continuous monitoring of the land surface (Woodcock et al., 2020).

Because of the increased ability to monitor the fate of post-disturbance landscapes with time series-based approaches, advances have been made in recent years related to the monitoring of degradation in the landscape opposed to more easily detectable land-use change (GFOI, 2020). Degradation in the landscape is often spectrally subtle and spatially isolated and at small spatial scale making detection in remotely sensed data, with accuracy, challenging.

A number of REDD+ countries have made use of freely available Landsat imagery, supplemented with recently available Sentinel data to develop long historical time series of data and facilitate monitoring of deforestation as well as degradation in forestlands (GFOI, 2020). These techniques can in principle be applied to other vegetated landscapes captured under Coastal Wetlands.

3.3.2 Attribution

Attribution is the process of associating observed land cover and cover changes with land-use and land-use change. Because different management and disturbance types have different impacts on carbon stocks and GHG emissions, knowledge of the cause of disturbance is needed not only to estimate areas of land-use and land-use change but also to estimate the associated GHG emissions and removals (IPCC, 2019). Attribution facilitates neither over- nor underestimating emissions from these lands by (GFOI, 2020):

- Determining if a change in forestland is temporary (e.g., a disturbance from sustainable logging), permanent (e.g., conversion to agricultural land or settlement), or the result of natural disturbance (e.g., cyclone.
- Assigning disturbance types to forest strata to enable representative methods for estimating emissions and removals to be applied.

Understanding the causes and drivers of natural and human-induced forest cover change and the subsequent forest recovery and succession dynamics enable the estimation of the impacts on carbon stock changes and the associated GHG emission (Kurz, 2010; Masek, 2011; Schroeder, 2011; Spalding, 2009).

Attribution can become particularly important in the context of coastal wetlands as the soil organic carbon pool may be the most significant source of emissions/removals[13]. Short and long term GHG releases from soil organic carbon can be significantly influenced by the land management applied and therefore attributing the change agent to the activity data can greatly improve the accuracy of GHG estimates. Attribution can also play a significant role in improving the quality of global datasets in their application at the national level.

Attribution typically requires a combination of information including, but not limited to, past and current land cover, management practices and country-specific decisions on a series of reporting rules. Typical datasets used in attribution include those with information relating to fires, forest management areas, agricultural areas, road coverage and urban areas (Mascorro et al., 2015). As data processing algorithms detect increasingly diverse change processes, the need to distinguish among the agents causing the change becomes critical. Not only do different change types have different impacts on natural and anthropogenic systems, they also provide insight into the overall processes controlling landscape condition.

3.4 Methods, approaches and tiers

Guidance for NGGIs produced by the IPCC are based on concepts of methods, approaches and tiers. In the context of AFOLU measurement, reporting and verification[14]:

- **A method refers to how emissions and removals of CO_2 are estimated.** The method applied to the AFOLU sector are either the gain-loss or the stock-difference method. The gain-loss method estimates annual emissions and/or removals separately and directly from the processes to which those are associated. The stock-difference method estimates net annual emissions or removals from the difference in total carbon stocks at two points in time divided by the number of intervening years.
- **An approach refers to how activity data is generated in the context of consistent representation of lands** and can be either Approach 1 - total land-use area, no data on conversions between land-uses, Approach 2 - total land-use area, including changes between categories, or Approach 3 - spatially explicit land-use conversion data.
- **A tier represents a level of methodological complexity** being either Tier 1 - the basic method, Tier 2 - the intermediate method and Tier 3 - the most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate as they rely on national specific data.

Adopting specific methods, approaches and tiers is driven by a combination of the purpose of the inventory and data availability. Most countries apply a mix of methods and tiers in developing inventory estimates utilising **key category analysis** to transparently[15] explain methodological choice for each category and subcategory as well as continuous improvement plans.

13 Noting that it is acceptable to report non-CO2 emission by source category without attribution to land-uses if emissions are estimated based on national statistics, without reference to individual land-uses (e.g., N2O emissions from soils).

14 For more in-depth detail of IPCC methods, approaches and tiers, specifically in the context of the AFLOU sector refer to the Methods and Guidance Document of the Global Forests Observations Initiative.

15 See **Section 6.1 Uncertainty estimation**

The stock-difference method requires consistent data collected over two points in time to generate emission/removals. This type of data set is unlikely to be available at a national level for carbon pools and gases in coastal wetland ecosystems. It is more likely that Tier 1 default emission factors or national data from smaller one-off data collection / research programs are available for application in the gain-loss method.

Additionally, it is most likely that a combination of Approach 1/2/3 may be used for activity data for the various land-use subcategories, noting that Approach 3 spatially explicit data is most effective in achieving time series consistency especially where there are multiple changes through time on a single area of land. Additionally Approach 3 data may be required in the context of results-based payments. However, it is also noted that spatially explicit (Approach 3) areas of seagrasses are unlikely to be available. Therefore, in the case of methods, approaches and tiers for reporting coastal wetland ecosystems in the NGGI:

- Most REDD+ countries who have included mangroves in their forest definition have adopted the gain-loss method, using either Approach 2 or Approach 3 activity data combined with Tier 1/2 emission factors.
- Where countries have repeated National Forest Inventory data that captures mangrove ecosystems then a stock-difference methodology may be applied.
- Where countries are not voluntarily reporting to REDD+ or where mangroves are not included in their forest definition[16] these areas may not be key categories and therefore adopting a gain-loss, Approach 1/2 and Tier 1 utilising default factors from the 2013 Wetlands Supplement would be sufficient.
- For areas of tidal marshes and seagrasses it is more likely that a gain-loss, Approach 1 and Tier 1 would be adopted for activities and/or subcategories where default data are available in the 2013 Wetlands Supplement[17]

3.5 Key category analysis

Key category analysis[18] is the IPCC's method for informing the allocation of resource to categories (or subcategories) of the NGGI with the aim of improving the accuracy of inventory estimates and can be used as the basis for methodological choice. Key category analysis enables the identification of categories or subcategories, (i.e. or activities or carbon pools) that have the greatest impact on the overall inventory estimates (or its uncertainty). These identified categories or subcategories should be the focus of stepwise continuous improvement toward higher Tier reporting in order to make the most efficient use of available resources (skilled people and money) and achieve cost-effectiveness.

16 See Section 2.2 Relevance to Forest Reference (Emission) Levels and Section 3.1 Land representation

17 See Section 3.6 Relevant carbon pools and gases and Section 4.2 Land-use categories for more details on available Tier 1 emissions factors

18 Key category analysis is described in detail in Volume 1, Chapter 4 of the 2006GL.

Key category analysis can be applied within subcategories, such as Coastal Wetlands, to establish an understanding of GHG impacts of various carbon pools, gases or activities within a category. When emissions/removals from a specific activity, such as conversion of wetlands to other land-uses, are estimated using the same methodology, but spread out among different land-use change categories, these should be identified and emission/removal estimates summed for this activity. The total magnitude should then be compared with the smallest category identified as key. If this sum is larger than the smallest category identified as key, the activity in question should be considered key.

It is recommended to conduct a key category analysis using the Tier 1 methods and default factors available in the 2013 Wetlands Supplement as a first step for inclusion of Coastal Wetlands in the NGGI. When conducting key category analysis at the subcategory level, the Good Practice Guidance for Land-use, Land-use Change and Forestry (IPCC, 2003) suggests that the significant subcategories are those that contribute at least 25 to 30 percent of the emissions or removals in the parent category to which they belong.

This does not mean that non-significant subcategories are omitted, but rather that Tier 1 methods applied if country specific data are not available. Significant subcategories (or pools within a category) could be taken to be those accounting for 25 to 30 percent or more of the GHG emissions or removals associated with a Coastal Wetland activity (category)[19].

Another possible (though not necessarily mutually exclusive) way to approach significance, would be to develop a set of rules to help ensure a consistent policy signal to prioritise the most relevant sources/sinks (GFOI, 2020). For example:

- The pool likely to be responsible for the largest cumulative emissions from the Coastal Wetland activity (or removals if the carbon stocks addressed by the activity are increasing) is the most significant.
- Other pools not already included can potentially be considered not significant if they behave in the same direction as the most significant pool (i.e., their carbon stocks increase or decrease when those from the most significant pool increase or decrease, respectively).
- On the other hand, pools expected to behave differently compared with the most significant pool are considered potentially significant, for inclusion at the same time as the most significant pool, or for prioritisation in a stepwise approach as better data become available.

Key categories identified in this context can assist in providing the basis upon which priorities can be set for the collection of nationally specific data from coastal wetland ecosystems in the context of broader policy objectives[20].

19 See Chapter 5.4, of 2003 IPCC Good Practice Guidance Land-use, Land-use Change and Forestry.

20 See Section 2.3 Relevance to broad policy objectives

Once identified key categories (or subcategories) should receive special consideration in terms of three important inventory aspects:

1. Focus the available resources for the improvement in data and methods onto categories identified as key.
2. Detailed higher tier methods should be selected for key categories. Any key categories where the good practice method cannot be used should have priority for future improvements.
3. Give additional attention to key categories with respect to quality assurance and quality control (QA/QC).

Key category analysis should be performed at the level of IPCC categories or subcategories at which the IPCC methods and decision trees are generally provided in the sectoral volumes. For coastal wetland ecosystems this would imply by activity, then by carbon pool/GHG as defined in the 2013 Wetlands Supplement.

Since it is not known at the outset of a NGGI which categories are key, and which accordingly need to be prioritised in the allocation of available resources, key category analysis may initially need to be undertaken using Tier 1 methods using a Level Assessment, known as Approach 1. Approach 1 can readily be accomplished using a spreadsheet analysis (see Box 8). Trend assessments, or Approach 2, can be applied when more than one year of inventory data are available. When the inventory estimates are available for several years, it is good practice to assess the contribution of each category to both the level and trend of the national inventory.

Box 8: Example of a key category level assessment (Approach 1)

The application of a key category analysis helps to identify priority categories for which methods, activity data, emission factors and other parameters should be considered for regular update, more rigorous checking and review and, where necessary or possible, improvements (IPCC, 2019). Guidance on the appropriate level of disaggregation of subcategories is available in the IPCC Guidelines. The example set out below applies the Approach 1 - Level Assessment (see Equation 4.1; Volume 1, Chapter 4 of the 2006 IPCC Guidelines) to identify key Wetland categories upon which to focus resources. Key categories are those that, when summed together in descending order of magnitude, add up to 95% of the cumulative total emissions under consideration (see Column G). In this abridged example only the IPCC Category Codes related to Wetlands are included. All estimates presented in the columns D and E have units of tonnes CO2-e. Decimals presented in columns F and G are dimensionless and represent the proportion of the subcategory to the total.

Approach 1 analysis – level assessment Wetlands subcategories

A	B	C	D	E	F	G
IPC Category Code	IPCC Category	GHG	Latest year estimate	Absolute value of latest year estimate	Level Assessment	Cumulative total of column F
4.C.2.c	**Wetlands converted to Grassland**	**CO_2**	**1792**	**1792**	**0.72**	**0.72**
4.A.2.c	**Wetlands converted to Forest Land**	**CO_2**	**331**	**331**	**0.13**	**0.86**
4.B.2.c	**Wetlands Converted to Cropland**	**CO_2**	**232**	**232**	**0.09**	**0.95**
4. D.1	Wetlan remaining Wetland	CO_2	112	112	0.05	1.00
4. D.1	Wetland remaining Wetland	CH_4	-9	9	0.00	1.00
Totals			2468	2486	1.00	1.00

In the table above, the Wetlands converted to Grassland/Forest Land/Cropland (bolded) with the GHG CO_2 are the three subcategories that cumulatively represent 95% of the total absolute emissions/removals.

Once the key categories have been identified it is useful to apply the same technique to carbon pools within the identified key categories to determine the focus of any rigorous checking, review or improvements to default or national datasets.

At this level of disaggregation, the IPCC Guidelines suggests that the significant subcategories are those that contribute at least 25 to 30 percent of the emissions or removals in the parent category to which they belong.

Box 8: Example of a key category level assessment (Approach 1)

Disaggregation to identify key carbon pools in key categories

A	B	D	E	F	G
IPC Category Code	IPCC Category	Latest year estimate	Absolute value of latest year estimate	Level Assessment	Cumulative total of column F
4.C.2.c	Above-ground Biomass	922	922	0.51	0.51
4.C.2.c	Soil Organic Carbon	511	511	0.29	0.80
4.C.2.c	Below-ground Biomass	210	210	0.12	0.92
4.C.2.c	Deadwood	140	140	0.08	
4.C.2.c	Litter	9	9	0.01	
Totals		1792	1792	1.00	

When considering subcategories, the level assessment (Column F) should be used rather than the cumulative total (Column G). In the example presented the key carbon pools are the above-ground biomass pool (51%) and the soil organic carbon pool (29%). Even though these two pools combined only add to 80% they are the only key subcategories as the remaining three pools individually make a contribution to the total of less than 25-30%.

3.6 Relevant carbon pools and gases

Coastal wetlands have high carbon stocks in soils (also called sediments), and for mangroves may also have high carbon stocks in the above-ground and below-ground biomass, including dead organic matter. These carbon pools are vulnerable to losses and associated carbon dioxide emissions when coastal wetlands are degraded and converted to alternative land-uses (e.g., through extraction and drainage for conversion to agriculture, aquaculture or construction of ports or dredging). Atmospheric removals of carbon occur with biomass accumulation and within soils when coastal wetlands are restored, rehabilitated and created. Methane and nitrous oxide can be relevant gases to consider for coastal wetlands and flooded lands especially related to aquaculture and drainage activities. Therefore, relevant carbon pools and gases are:

- Above-ground biomass and dead organic matter. These can be particularly relevant for mangroves
- Below-ground biomass
- Soil carbon stocks in organic and mineral soils
- Methane
- Nitrous oxide

Above-ground and below-ground biomass are most relevant to mangrove ecosystems where they are harvested for wood products, including fuel wood and timber (**Figure 5: Tall Bruguiera mangroves in Fiji (Image: C. Cameron)**) or when converted to other lands uses. Carbon stocks in downed (dead organic matter) wood and litter of mangroves is low in some cases but may be relevant pools in some landscapes, e.g., those affected by cyclones (**Figure 6**).

Soil organic carbon guidance is provided in the 2013 Wetlands Supplement for estimating emissions from extraction (e.g., excavation or drainage) of coastal wetlands and conversion to other land-uses which include emissions from soils to 1 m depth, noting that there can be significant soil carbon stocks in coastal wetlands at depths greater than 1 m. Countries can include soil carbon at depths greater (or less) than 1 m at Tier 2 and 3 if relevant (e.g., where activities excavated coastal wetlands to greater than 1 m depth and where data from deeper soil layers was available).

Soil carbon stocks and sequestration rates varies with wetland type and is influenced by latitude and precipitation (Atwood et al., 2017; Hinson et al., 2019), hydro-geomorphology (Sasmito et al., 2020). Reported soil carbon stocks and sequestration rates for coastal wetlands from key global and regional data sources have been summarised (Hagger & Lovelock, 2021).

Methane emissions can be relevant in landscapes where:

- Rewetting of soils occurs with mangrove or tidal marsh restoration, rehabilitation or creation (2013 Wetlands Supplement) (Figure 7).
- There are landscapes with brackish aquaculture and other constructed wate bodies, e.g., those with drains and channels associated with drained wetlands (2019 Wetlands Refinement).

Methane is produced in anoxic (low oxygen) environments of organic waterlogged soils. The level of methane emissions is sensitive to the proportion of seawater in the water flooding soils as well as to temperature, the plant community present and other environmental factors. For example, when the water flooding soils is saline methane emissions are low, while under freshwater conditions, methane emissions are high.

Nitrous oxide is produced from ecosystems when nitrogen inputs are high, and thus nitrous oxide emissions are relevant for intensive and semi-intensive aquaculture when aquaculture species are fed nitrogen-rich food. Nitrous oxide is a relevant flux to estimate where landscapes have intensive and semi-intensive aquaculture. Nitrous oxide emission in the 2013 Wetlands Supplement is estimated as a function of aquaculture yields.

Which carbon pools and GHGs that countries consider relevant to their inventory is dependent on whether particular land-uses and activities are defined as **key categories**[21].

21 See **Section 3.5 Key category analysis**)

Figure 5: Tall Bruguiera mangroves in Fiji (Image: C. Cameron)

Box 9: Incremental improvement of estimates of change in mangrove soil carbon in Australia
Australia introduced mangroves and tidal marshes into their inventory in 2015. They used national data to estimate carbon stocks in soils and estimated change in soil organic carbon from excavation using a simple Tier 1 assumption that all soil organic carbon is mineralised in the year of excavation. The plan is to improve this approach over time incorporating coastal wetland soil carbon and biomass within Australia's Full Carbon Accounting Model (FullCAM).

Figure 6: Cyclone affected mangrove in Yacuna, Fiji (Image: C. Cameron)

Figure 7: Community rewetting project and tidal channel re-creation in South Sulawesi (Photo: Rio Ahmad, Blue Forests)

4. Coastal Wetland methodological considerations

This chapter describes the activity-based and managed land proxy approaches for including Coastal Wetlands into NGGIs and provides a case study from the United States for estimation using the managed land proxy approach (**Box 10**). It also summarises the IPCC estimation methodologies for specific management activities in mangroves, tidal marshes and seagrass meadows, and provides scenarios on how to estimate emissions and removals with land-use changes over time.

4.1 Activity-based versus managed land proxy approach

As in terrestrial ecosystems, long-term monitoring and verification of carbon stock changes in coastal wetlands are closely linked to the ability to measure carbon. Thus, monitoring and verification might pose challenges in seagrasses and tidal marshes, while less so in mangroves, and are harder to implement at the national scale rather than at the project scale.

The IPCC provides methods for estimating anthropogenic GHG emissions and removals (CO_2, CH_4 and N_2O) associated with specific management activities including aquaculture, salt production, extraction, drainage, rewetting, revegetation and creation, and forest management practice in mangroves (2013 Wetlands Supplement), and recently flooded lands, including reservoirs, canals and ditches, and constructed ponds (freshwater or saline) (2019 Wetlands Refinement). Methodology development for these management activities were chosen based on significant land-use changes that have occurred in coastal wetlands worldwide (e.g., Valiela et al., 2001) that can produce large quantities of CO_2 emissions from disturbance of carbon stocks in soils and biomass) or can result in removals of CO_2 from rewetting or restoration of coastal wetlands.

Whilst this focus is on management activities, it is recognised that the 2006 IPCC Guidelines maintain six land-use categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Lands (e.g., bare soil, rock, ice, etc.), and these categories are used for estimating anthropogenic GHG emissions and removals from land-use, land-use change and forestry (LULUCF) (i.e., managed lands) for three carbon pools (living biomass, dead organic matter and soil organic carbon). Emissions and removals are not reported for unmanaged lands; the area for those lands are tracked over time (Troxler et al., 2018).

Two alternative methods for estimating CO_2 emissions and removals are given: (1) Stock difference method based on carbon stocks of each carbon pool before and after the land-use; and (2) Gain-loss method including carbon fluxes (e.g., growth or transfer from another carbon pool). An assumption of the LULUCF approach is that the sum of carbon gains and losses is equivalent to net stock changes and equivalent to total emissions and removals. Thus, the inventory compiler is not restricted to the use of carbon stock data or CO_2 flux data, as long as the general equations used (stock change or gain-loss) are complete, accurate and consistent, avoiding over- and under-estimates (Troxler et al., 2018).

When developing Coastal Wetland estimates for NGGI reporting, countries can adopt either the:

1. **Activity-based approach -** considering only specific land-use or management activities in managed Coastal Wetlands that have the largest global influence on GHG emissions and removals.
2. **Managed land proxy** - considering all lands that are defined as managed (this is the approach adopted by the United States, Canada and Brazil) (Ogle et al., 2018).

Countries can apply an appropriate approach based on the data they have available. Many countries are likely to have more data on management activities than coverage of all managed and unmanaged coastal wetlands that is needed to adopt the managed land proxy approach.

The activity-based approach allows countries, at a minimum, to account for GHG emissions and removals for the management activities that are the largest sources and sinks. If adequate data is available, it is *good practice* to report the managed land proxy estimates (**Box 10**), as well as the indicative estimates of the anthropogenic component of the total GHG emissions (IPCC, 2019). By applying comprehensive inventory reporting of managed coastal wetlands, countries can identify opportunities for reducing emissions through protection and restoration of coastal wetlands.

Box 10: Inclusion of coastal wetlands into the United States (US) national greenhouse gas inventory

The US has included managed coastal wetlands in its yearly NGGI since its 2017 submission to the UNFCCC, and time series wetland data are updated on an annual basis. The US reports both sources and sinks associated with managed coastal wetlands. However, because of the high density of populations in coastal areas, the analysis considers all coastal wetlands[22] within the conterminous US as 'managed lands', and therefore all estimates of CO_2 emissions and removals, CH_4 emissions and N_2O emissions from aquaculture are included in the inventory. Seagrasses are not currently included due to insufficient data on distribution, change through time, and carbon stocks.

The inventory analysis quantifies the extent of remaining coastal wetlands, and coastal wetlands that are converted to or from other land-use categories. The land-use categories applied within this extent of managed coastal wetlands include Settlements, Cropland, Grassland, Forest Land (dry), Wetland (both palustrine wetlands and estuarine wetlands), and Other Land. Activity data on land-use and land-use change are derived from the National Oceanic and Atmospheric Administration Coastal Change Analysis Program, which uses a combination of satellite imagery, tide station data, and national soil survey databases.

Emissions and removals from these wetland areas are determined for four primary conversion types: vegetated coastal wetlands that remained vegetated coastal wetlands (VCW–VCW); unvegetated open water coastal wetlands that were converted to vegetated coastal wetlands (UOWCW–VCW); land that was converted to vegetated coastal wetlands (L–VCW) and vegetated coastal wetlands that were converted to unvegetated open water coastal wetlands (VCW–UOWCW). Coastal wetland gains from both restoration and creation of coastal wetlands, and from gradual sea level rise, flooding previously drained low-lying coastal land behind hydrological barriers are captured in the US inventory under L-VCW. The US expanded on the specific management activities in the 2013 Wetlands Supplement to include emissions from human-induced subsidence and erosion (conversion to open water). Other activities considered important, but not yet included, are CH_4 emissions from impaired tidal drainage and forestry activities on tidally influenced forests.

GHGs are estimated for remaining coastal wetlands (VCW–VCW) from gains and losses of carbon stocks and emissions of CH_4. In the 2018 inventory, only soil CO_2 emissions and removals were reported, as soils have been recognised as the largest carbon pool. The following year biomass was added. A large release of soil carbon occurs with loss of vegetated coastal wetland through conversion to open water (VCW–UOWCW), primarily because of subsidence from changes in river hydrology, sediment supply disruption, and oil and gas extraction. Soil carbon is also released over-time from drainage through conversion to settlements, croplands and grasslands. These emissions continue until the soil carbon stock is depleted or soil water management changes. However, estimates of conversion of coastal wetlands to these other land-use categories are covered under other AFOLU categories, and therefore they are not included in the managed coastal wetland contribution to the US inventory.

22 Defined as "all privately owned and publicly owned coastal wetlands (coastal ecosystems with organic and mineral soils that are covered or saturated for part of the year by tidal freshwater, brackish or saline water and are vegetated by vascular plants and may extend seawards to the maximum depth of vascular plant vegetation) along the oceanic shores of the conterminous United States".

Box 10: Inclusion of coastal wetlands into the United States (US) national greenhouse gas inventory

Wetlands are highly connected systems that are influenced by indirect landscape-scale human activities, such as upstream water diversions and sediment supply disruptions. This makes on-site attribution of emissions and removals to a specific management practice difficult to include in inventories. The US addressed this challenge of applying the activity-based approach to GHG estimation by recognising that all coastal wetlands are managed, and accounting for emissions and removals irrespective of the driver/s (Crooks et al., 2018; Troxler et al., 2018).

4.2 Land-use categories

The IPCC provides guidance for NGGI relevant to managed coastal wetlands and human-made and managed flooded land under the AFOLU sector within the following categories:

- Managed Forest Land, including Forest Land remaining Forest Land, and Land converted to Forest Land (2006 IPCC Guidelines, Volume 4, Chapter 4) - mangroves may fall into this category if they meet the country's definition of Forest Land, for example if mangroves (or sub-strata of mangroves) are included in the countries FREL/FRL. If not, they fall into Coastal Wetlands.
- **Coastal Wetlands -** consideration of specific management activities in mangroves, tidal marshes and seagrasses that can result in change in land-use category, including forest management practice in mangroves, extraction, aquaculture, salt production, drainage, rewetting, revegetation and creation, and rewetting soils (2013 Wetlands Supplement, Chapter 4). See **Section 3.1 Land representation** for examples of these activities.
- **Cropland, including Cropland remaining Cropland, and Land converted to Cropland for paddy rice cultivation** (2006 IPCC Guidelines, Volume 4, Chapter 5).
- **Managed Flooded Land, including Flooded Land remaining Flooded Land, and Land converted to Flooded Land for reservoirs and other constructed water bodies**, e.g., freshwater or saline ponds, canals or ditches, and aquaculture ponds (2019 Wetlands Refinement, Chapter 7).

To incorporate coastal wetlands in NGGI, countries can undertake a key category analysis, and estimate emissions and removals using Tier 1 emission factors and methods for land-use changes from the key management activities in coastal wetlands **(Table 6: Activities, vegetation types, carbon pools and greenhouse gases relevant to coastal wetlands and where they are discussed in the IPCC Guidance**), and human-made wetlands in coastal regions (**Table 7**). How these activities are applied in mangrove, tidal marsh and seagrass to generate emissions/removals for NGGI at Tier 1 are presented in **Section 4.3: Examples of time series land-use conversions**. Countries seeking to report other management practices in coastal wetlands or human-made wetlands not covered should, where feasible, develop domestic emission factors, with a priority on key categories.

Table 6: Activities, vegetation types, carbon pools and greenhouse gases relevant to coastal wetlands and where they are discussed in the IPCC Guidance

Activity /land-use	Sub-activity	Vegetation type	Relevant carbon pools and GHGs	Where this is in the IPCC Guidance
Forest management practices	Planting, thinning, harvest, wood removal, fuelwood removal, charcoal production	Mangrove	Above-ground biomass, dead organic matter and soil carbon	2019 Refinement, Chapter 12 (Harvested Wood Products) 2013 Wetlands Supplement, Chapter 4, Section 4.2.1
Extraction	Excavation for ports, harbours and marina construction, and filling or dredging	Mangrove, tidal marsh seagrass	Above-ground and below-ground biomass, dead organic matter, soil carbon	2013 Wetlands Supplement, Chapter 4, Section 4.2.2
Extraction	Aquaculture construction	Mangrove, tidal marsh	Above-ground and below-ground biomass, dead organic matter, soil carbon	2013 Wetlands Supplement, Chapter 4, Section 4.2.2
Extraction	Salt production construction	Mangrove, tidal marsh	Above-ground and below-ground biomass, dead organic matter, soil carbon	2013 Wetlands Supplement, Chapter 4, Section 4.2.2
Pond use	Aquaculture use	Mangrove, tidal marsh and seagrass	CH_4 and N_2O emissions from aquaculture use	CH_4 – 2019 Wetlands Refinement, Chapter 7, Section 7.3.1.2 (Other constructed water bodies) N_2O - 2013 Wetlands Supplement, Chapter 4, Section 4.3.2
Drainage	Agriculture, forestry, settlements, mosquito control	Mangrove, tidal marsh	Above-ground and below-ground biomass, dead organic matter, soil carbon	2013 Wetlands Supplement, Chapter 4, Section 4.2.4

Activity /land-use	Sub-activity	Vegetation type	Relevant carbon pools and GHGs	Where this is in the IPCC Guidance
Drain use (canals and ditches)	Agriculture, forestry, mosquito control, aquaculture	-	CH_4 emissions from drain use	2019 Wetlands Refinement, Chapter 7, Section 7.3.1.2 (Other constructed water bodies)
Rewetting, revegetation and creation	Conversion of drained to saturated soils by restoring hydrology and reestablishment of vegetation	Mangrove, tidal marsh, seagrass	Mangroves: above-ground and below-ground biomass, dead organic matter, soil carbon Tidal marsh and seagrass: soil carbon only	2013 Wetlands Supplement, Chapter 4, Section 4.2.3
Rewetting, revegetation and creation	From change to natural vegetation following modifications to restore hydrology	Mangrove, tidal marsh	CH_4 emissions	2013 Wetlands Supplement, Chapter 4, Section 4.3.1

Table 7: Human-made and managed flooded land and IPCC guidance provided

Human-made wetland categor (RAMSAR class1)	Wetlands subcategories in IPCC	Relevant GHGs emissions	Where this is in the IPCC Guidance
Water storage areas	Reservoirs	CO_2 and CH_4	2019 Wetlands Refinement, Chapter 7, Section 7.3.2.1 (CO_2); Section 7.3.1.2 and 7.3.2.2 (CH_4)
Ponds	Other constructed waterbodies (freshwater and saline ponds used for agriculture, aquaculture or recreation)	CO_2 during construction of aquaculture and salt production ponds, and CH_4 during use	2013 Wetlands Supplement, Chapter 4, Sections 4.2.2 (CO_2). 2019 Wetlands Refinement, Chapter 7, Section 7.3.1.2 (CH_4).

Human-made wetland categor (RAMSAR class1)	Wetlands subcategories in IPCC	Relevant GHGs emissions	Where this is in the IPCC Guidance
Canals and drainage channels or ditches	Other constructed waterbodies (canals and ditches)	CH_4 during use	2019 Wetlands Refinement, Chapter 7, Section 7.3.1.2 (CH_4).
Aquaculture	Other constructed waterbodies (freshwater and saline ponds), Excavation (aquaculture construction), Aquaculture use	CO_2 during construction of aquaculture ponds, CH_4 and N_2O during aquaculture use	2013 Wetlands Supplement, Chapter 4, Sections 4.2.2 (CO_2). 2019 Wetlands Refinement, Chapter 7, Section 7.3.1.2 (CH_4). 2013 Wetlands Supplement, Chapter 4, Section 4.3.2 (N_2O)
Irrigated land (if cultivated)	Cropland (rice paddies)	CO_2	2016 Guidelines, Volume 4, Chapter 5
Seasonally flooded agricultural land	Cropland (rice cultivation)	CH_4	2016 Guidelines, Volume 4, Chapter 5
Seasonally flooded agricultural land including intensively managed or grazed wet meadow or pasture	Coastal wetlands	CO_2 and CH_4 for rewetted draine land that was previously coastal wetlands	2013 Wetlands Supplement, Chapter 4, Section 4.2.3 (CO_2), Section 4.3.1 (CH_4)
Salt exploitation sites	Coastal wetlands	CO_2 during construction of salt production ponds	2013 Wetlands Supplement, Chapter 4, Sections 4.2.2 (CO_2).
Wastewater treatment areas	Constructed wetlands for wastewate treatment	CH_4 and N_2O	2013 Wetlands Supplement, Chapter 6, Section 6.2 (CH_4) and Section 6.3 (N_2O)

1 Source: Ramsar (2014)

4.2.1 Mangroves

The 2013 Wetlands Supplement states that it is *good practice* to report mangroves in the appropriate national land-use category according to the national forest definition and to consider when forest management practices may occur on mangroves classified unde land-use categories other than Forest Land. Both carbon dioxide and non-carbon dioxide emissions/removals are estimated from six coastal wetland management activities that can occur within mangrove ecosystems (**Table 8: Land-use conversion categories in mangroves**).

Table 8: Land-use conversion categories in mangroves

Event	Description of possible activities	NGGI Land-use category at T1	NGGI Land-use category at T2
Forest management practices in mangroves	Planting, thinning, harvest, wood removal, fuelwood removal, charcoal production where there is degradation or enhancement but no change of land use.	Forest Land;	Forest Land
	Planting, thinning, harvest, wood removal, fuelwood removal, charcoal production where there is degradation or enhancement but no change of land use where these activities result in the conversion to/from Forest Land to/from other land-uses.	Wetland	Forest Land
		Forest Land	Wetland
Extraction	Aquaculture and salt pond construction, excavation to enable port, harbour and marina construction and filling or dredging to facilitate raising the elevation of land.	Forest Land; Wetland	Settlement; Cropland; Other land; Wetland
Drainage	Agriculture, forestry, mosquito control	Forest Land; Wetland	Cropland, Other land
Rewetting, revegetation and creation	Conversion from drained to saturated soils by restoring hydrology and reestablishment of vegetation	Cropland;	Forest Land; Wetland
Rewetted soils	Methane emissions from change to natural vegetation following modifications to restore hydrology	Cropland;	Forest Land; Wetland
Aquaculture (use)	Nitrous oxide emissions from aquaculture use. A country can exclude nitrous oxide emissions that occur from aquaculture activities where no mangroves, tidal marsh or seagrass meadows exist (i.e. outside of coastal wetland areas).	Other land; Wetland	Other land; Wetland

Not all carbon pools have Tier 1 default values available for all events (**Table 9: Available Tier 1 emission factors for reporting activities in mangroves**). In the absence of national data, these carbon pools need not be reported.

For extraction activities, emissions and removals are estimated for the initial change in carbon stocks that occur during the year the extraction activities take place. Once the activities are completed, these lands are continually tracked but emissions and removals are reported as zero at Tier 1. Tracking of such lands requires spatially and temporally explicit activity data (i.e., Approach 3) for these lands.

Forest management practices in mangroves, drainage and rewetting are reported based on the area of land where it occurs. These lands are monitored through time and emissions and removals subsequently reported in the annual inventory.

Table 9: Available Tier 1 emission factors for reporting activities in mangroves

Event	Above ground Biomass	Below ground Biomass	Litter	Dead wood	Soil Carbon (Mineral / Organic)	Non-CO2
Forest management practices in mangroves	Yes	Yes	No; unless a land-use change occurs	No; unless a land-use change occurs	No; unless there is drainage or rewetting	No
Extraction (e.g. aquaculture, saltpond)	Yes	Yes	No	Yes	Yes[2]	No
Aquaculture (use)	No	No	No	No	No	Yes; N_2O emissions
Drainage	Yes[1]	Yes	No	Yes	Yes[2]	No
Rewetting, revegetation and creation[3]	Yes; tree growth	Yes	No	No	Yes; Carbon burial	Yes; CH_4 emissions
Rewetted soils	Yes; tree growth	Yes	No	No	Yes; Carbon burial	Yes; CH_4 emissions

1 If burning accompanies drainage, it is good practice to report emissions from changes in those C pools.

2 Stock difference approach is suggested if a country uses mineral soil category; Gain-Loss approach is suggested if country use organic soil category

3 If the rewetting and revegetation activity results in patches of biomass (if coverage data are available), EFRE > 0 should only be applied when the mangrove canopy, tidal marsh plant community or seagrass meadow covers at least 10% of the overall area. This consideration follows the definition of forest (Table 4.2, Chapter 4, Volume 4, 2006 IPCC Guidelines).

4.2.2 Tidal marshes

Both carbon dioxide and non-carbon dioxide emissions/removals are estimated from five management activities that can occur within tidal marshes (**Table 10: Land-use conversion categories for tidal marshes**).

Table 10: Land-use conversion categories for tidal marshes

Event	Description	NGGI Land-use category at T1	NGGI Land-use category at T2
Extraction	Excavation to enable port, harbour and marina construction and filling or dredging to facilitate raising the elevation of land. Aquaculture (construction) Salt production (construction)	Wetland	Settlement; Cropland; Other land; Wetland
Drainage	Agriculture, forestry, mosquito control	Wetland	Cropland, Other land
Rewetting, revegetation and creation	Conversion from drained to saturated soils by restoring hydrology and reestablishment of vegetation	Cropland	Wetland
Rewetted soils	Methane emissions from change to natural vegetation following modifications to restore hydrology	Cropland	Wetland
Aquaculture (use)	Nitrous oxide emissions from aquaculture use	Other land; Wetland	Other land; Wetland

Guidance related to reporting of activities in tidal marshes at Tier 1 indicates that emissions from the soil and non-carbon dioxide emissions are most important. Within these ecosystems increases in biomass stocks in a single year is assumed equal to biomass losses from mortality in that same year leading to no net change. Therefore, across all reported activities in this ecosystem there is no requirement to report changes in biomass at Tier 1 (**Table 11: Available Tier 1 emission factors for reporting activities in tidal marshes**).

Table 11: Available Tier 1 emission factors for reporting activities in tidal marshes

Event	Above-ground Biomass	Below-ground Biomass	Litter	Dead wood	Soil Organic Carbon	Non-CO2
Extraction	No	No	No	No	Yes	No
Aquaculture (use)	No	No	No	No	No	Yes; N_2 emissions
Drainage[1]	No	No	No	No	Yes	No
Rewetting, revegetation and creation[2]	No	No	No	No	Yes	Yes; CH_4 emissions
Rewetted soils	No	No	No	No	Yes; Carbon burial	Yes; CH_4 emissions

1 If burning accompanies drainage, it is good practice to report emissions from changes in those C pools.

2 If the rewetting and revegetation activity results in patches of biomass (if coverage data are available), EFRE>0 should only be applied when the mangrove, tidal marsh plant or seagrass canopy covers at least 10% of the overall area. This consideration follows the definition of forest (Table 4.2, Chapter 4, Volume 4, 2006 IPCC Guidelines).

4.2.3 Seagrass meadows

In seagrass meadows, only carbon dioxide and non-carbon dioxide emissions from three management activities are relevant (**Table 12: Land-use conversion categories for seagrass meadows**). Guidance related to reporting of activities in seagrasses at Tier 1 indicates that emissions from the soil and non-carbon dioxide emissions are most important (**Table 13**).

Table 12: Land-use conversion categories for seagrass meadows

Event	Description	NGGI Land-use category at T1	NGGI Land-use category at T2
Extraction	Excavation to enable port, harbour and marina construction and filling or dredging to facilitate raising the elevation of land.	Wetland	Settlement; Cropland; Other land; Wetland
Aquaculture (use)	Nitrous oxide emissions from aquaculture use.	Other land; Wetland	Other land; Wetland
Rewetting, revegetation and creation	Reestablishment of vegetation on undrained soil.	Wetland	Wetland

Table 13: Available Tier 1 emission factors for reporting activities in seagrass meadows

Event	Above-ground Biomass	Below-ground Biomass	Litter	Dead wood	Soil Carbon (Mineral / Organic)	Non-CO_2
Extraction	No	No	No	No	**Yes**[1]	No
Aquaculture (use)	No	No	No	No	No	**Yes; N_2O emissions**
Rewetting, revegetation and creation	No	No	No	No	**Yes**	No

1 Tier 1 assumption is that all seagrass soils are mineral.

4.3 Estimating emissions and removals

4.3.1 Time-series land-use conversions

The estimation of emissions and removals requires, in some cases, a combination of methodologies which, if care is not taken, can lead to double-counting or omission of emissions or removals. It is good practice for countries to map the spatial extent of all coastal ecosystems and change in area through time, regardless of whether they are managed or unmanaged, in order to accurately determine the key categories from which to estimate GHG emissions and removals across a time series for NGGI reporting. An example of typical land-use conversions that may occur over time in mangrove (Scenario 1), and how to represent these transitions in land-use mapping, and estimate their associated emissions and removals at each time period is provided in **Appendix A**. An example of how transitions in seagrass meadows may be reported by countries is also given (Scenario 2). There are gaps in knowledge of the extent, carbon pools, emission factors and activities for seagrass, however countries can plan to assemble these data sources if planning to include seagrass in NGGI in the future (e.g., Oreska et al. (2020) for data available for seagrass in Virginia, USA).

4.3.2 Emissions and removals from forest management

The 2013 Wetlands Supplement provides Tier 1 emission factors for mangrove biomass carbon stocks and tree growth. Given the large difference of emissions/removals impacts resulted from forest management activities in subnational scales (**Box 11**), it is good practice to improve emissions factor to Tier 2/3 level.

Box 11: Forest management activities in mangroves

Mangroves are subject to forestry activities or forest management following their wood product extraction in some Southeast Asian countries. Approximately 30,000 ha of mangroves in Matang, Malaysia have been rotationally extracted every 30 years for the last century, fulfilling the region's demand for commercial charcoal (Adame et al., 2018; Shaharuddin et al., 2005). Moreover, 82,120 ha of mangroves in Bintuni Bay, Indonesia are designated as production forest (Sillanpää et al., 2017). Here, mangrove stands specifically *Rhizophora spp*. and *Bruguiera spp*. are also selectively extracted for commercial wood chip products. Both activities apply a similar forest management approach (i.e., rotational logging operation), but the clear-cutting method is applied in Matang and selective logging for specific species is applied in Bintuni. Logging rotation period between two sites is also different which may be due to different rates of biomass regrowth and consequently time required for regenerating mangroves to achieve biomass at the same level as the pre-disturbance condition. Matang Forest Management applies approximately 30 years of rotational logging operation (Adame et al., 2018), while 25-35 years of management period is applied in Bintuni (Sillanpää et al., 2017). Therefore, CO_2 emissions and removals impact due to forest management in mangrove may vary depending on the wood extraction approaches. Some studies have generated emissions/removals factor in Matang (Adame et al., 2018) and Bintuni (Sasmito et al., 2020), and introduced a suitable approach to monitoring logging activities as well as mangrove recovery (Lucas et al., 2020).

Overall, forest management in mangroves consists of two activities:

1. Logging or wood extraction phase (normally occurred within no more than 1 year)
2. Regenerating phase (occurred more than one year)

Consequently, detailed Tier 2/3 level NGGI monitoring should consider multiple emissions/removals factor for each carbon pool and phase (**Figure 8: Possible dynamics projection of carbon stock pools and their portion of changes across logging and regenerating phases (Source: S. Sasmito)**). The wood extraction phase directly generates nearly 100% of above-ground biomass loss and 99% of dead organic matter increase. During this phase, below-ground biomass and soil carbon pools generally remain, except for certain logging areas used for transporting and storing the extracted wood.

By contrast, the regeneration phase generates more complex and different emission/removal directions of each carbon pool over various periods. These carbon pool dynamics include above-ground biomass accumulation, dead organic matter loss, below-ground biomass loss as well as accumulation, and soil organic carbon accumulation. Activity data (i.e., time since regeneration) play a critical role in estimating emissions/removals during a regeneration phase.

Many studies have documented that biomass accumulation from net primary productivity is not linear and their magnitudes vary depending on the forest stages (Phan et al., 2019; Salmo et al., 2013), while IPCC provides only a single Tier 1 removal factor for mangrove tree growth. Following a systematic review which compiled extensive datasets related to mangrove tree growth from different sites (Sasmito et al., 2019), it is suggested that total biomass growth rates are in the order of 4.0 ± 2.5 tonnes C ha^{-1} yr^{-1} for the first 15 years and 7.0 ± 2.1 tonnes C ha^{-1} yr^{-1} between 15 – 40 years of age.

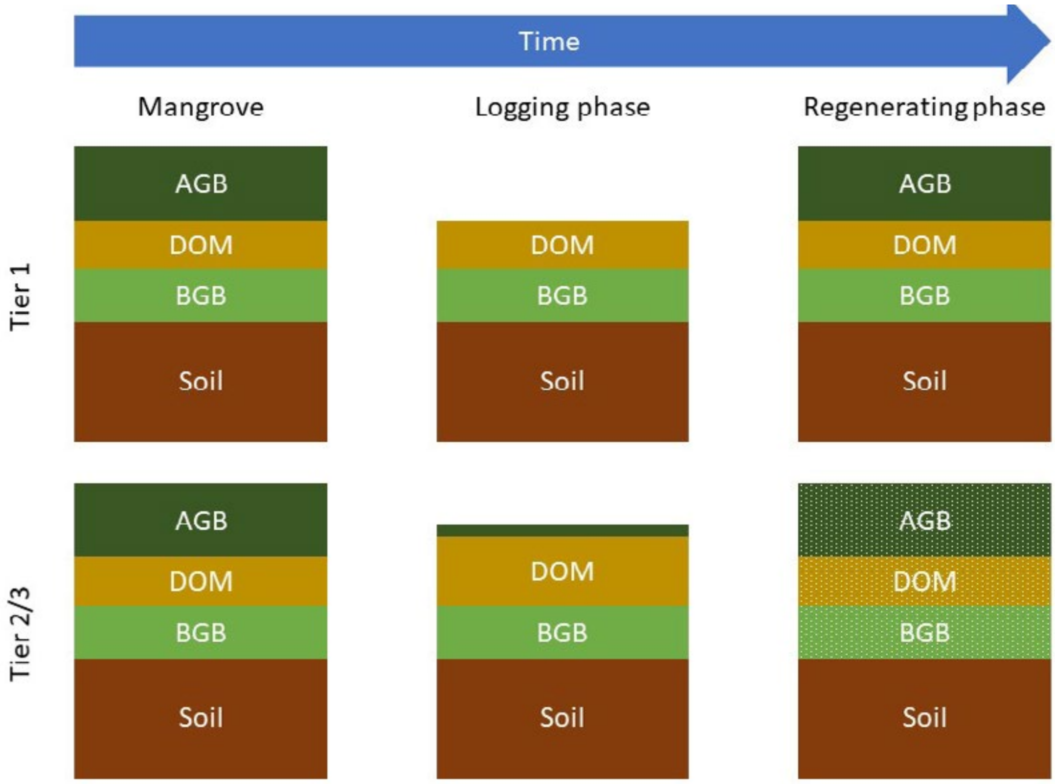


Figure 8: Possible dynamics projection of carbon stock pools and their portion of changes across logging and regenerating phases (Source: S. Sasmito)

Patterned colours indicate different rates and change directions (emissions/removals) during the regenerating phase depending on the time since regeneration.

ABG: above-ground biomass, DOM: Dead organic matter, BGB: below-ground biomass.

Table 14: Tier 1 and available data for Tier 2/3 improvement on carbon stocks change following different phases of forest management

ABG: above-ground biomass, DOM: Dead organic matter, BGB: below-ground biomass.

Tiers	Carbon pools	Carbon stocks change (loss/gain)[1]		Regenerating period	Reference
		Logging	Regenerating		
Tier 1[2]	AGB	-(100%)	+(9.9) (95% CI = 9.4-10.4) tonnes dry matter ha^{-1} yr^{-1}	NA	IPCC (2014)
	DOM	No change	NA	NA	IPCC (2014)
	BGB	-(100%)	+(0.49) (R/S ratio) [3]	NA	IPCC (2014)
	Soil	No change	+(1.62) tonnes C ha^{-1} yr^{-1}	NA	IPCC (2014)

Tiers	Carbon pools	Carbon stocks change (loss/gain)[1]		Regenerating period	Reference
		Logging	Regenerating		
Available data for Tier 2/3 improvement	AGB+BGB	-(70 ± 33%) [4]	+(4.0 ± 2.5) tonnes C ha^{-1} yr^{-1} [5]	1-15 years	Sasmito et al. (2019)
			+(7.0 ± 2.1) tonnes C ha^{-1} yr^{-1} [5]	15-40 years	Sasmito et al. (2019)
		-(100%)	+(3.6 ± 1.1) tonnes C ha^{-1} yr^{-1} [5]	1-25 years	Sasmito et al. (2020)
			+(4.4 ± 0.0) tonnes C ha^{-1} yr^{-1} [5]	1-12 years	Adame et al. (2018)
			≤ +(1) tonnes C ha^{-1} yr^{-1}	12-62 years	Adame et al. (2018)
	DOM	+(99%)	-(0.98) % yr^{-1}	1-25 years	Sasmito et al. (2020)
			+(0.80) tonnes C ha^{-1} yr^{-1}	1-35 years	Adame et al. (2018)
	Soil	-33 ± 13 % [4]	No change	1-30 years	Sasmito et al. (2019)
		No change	No change	1-25 years	Sasmito et al. (2020)
			+(5.7±0.2) tonnes C ha^{-1} yr^{-1} [5]	1-10 years	Adame et al. (2018)
			-(5.7±0.2) tonnes C ha^{-1} yr^{-1} [5]	10-40 years	Adame et al. (2018)
			+(5.7±0.2) tonnes C ha^{-1} yr^{-1} [5]	>40 years	Adame et al. (2018)

1 minus indicates carbon stocks loss, while positive indicates carbon stocks gain

2 Tier 1 data presented in this table are numbers obtained from Tropical Wet region presented in the 201 Wetlands Supplement

3 BGB accumulation during regenerating phase can be calculated by using root/shoot ratio

4 mean ± standard error

5 mean ± standard deviation

4.3.3 Example of estimating emissions and removals from extraction

Converted mangroves into aquaculture commonly consist of three sub-activities:

1. Construction
2. Use
3. Discontinued phases (IPCC, 2014)

The period of each sub-activity varies depending on the historically tracked activity data, creating complexity in estimating emissions/removals between sub-activity transition. For construction sub-activity, emissions and removals are estimated for the initial change in carbon stocks that occur during the year the extraction activities take place. Tier 1 provides default data on the initial carbon stocks (**Table 16**) and it is assumed that construction sub-activity generates complete loss of above-ground biomass, dead organic matter, and top 1 meter soil carbon pools. Once this construction is completed, these lands are continually tracked (use sub-activity) but carbon dioxide emissions and removals are reported as zero at Tier 1 with potential non-carbon dioxide (methane and nitrous oxide) emissions are monitored depending on the salinity and yield (**Figure 9: Possible dynamics projection of carbon stock pools and their portion of changes across different aquaculture sub-activities (construction, use, and discontinued) (Source: S. Sasmito)**). Methane emissions may be monitored continuously during discontinued activity.

Key opportunities to improve the future estimation of emissions/removals related to extraction are by reporting excavation depth and detailed soil organic carbon pool stratification (i.e., mineral or organic soils). Tier 1 provides default soil organic carbon stocks data for the first 1 meter with possible excavation depth up to 1.5 meters. However, some recent studies in tropical wet mangroves suggest that soil organic carbon stocks can be up to 3 meters (Arifanti, 2019; Kauffman et al., 2020; Sasmito et al., 2020). Incorporating detailed Tier 2/3 soil organic carbon stock data and more accurate pond depth information will improve NGGI reporting substantially, specifically for the construction sub-activity where biomass removals and soil extraction are initiated.

Moreover, it is currently still uncertain whether soil organic carbon accumulation and/or loss are occurred during the use and discontinued sub-activities. Further studies on sediment carbon burial and dating across these sub-activities will also substantially improve NGGI reposting in addition to existing nitrous oxide and methane emissions reporting from Tier 1.

Tier 1 considers mangrove soils as either mineral or organic soils. Except for mangroves which are collocated with peatlands, most reported wet tropic soil organic carbon stocks may be considered as mineral soils with their mean soil organic carbon content less than 30% (Kauffman et al., 2020). Stock difference methods are suggested for mineral soils, while gain-loss methods are suggested for organic soils (IPCC, 2014). For Tier 2/3 improvement, the choice of method may depend on the availability of the emissions/removals factor data. For the case of three excavation sub-activities and organic soils occurring, the combination of the stock difference and gain-loss methods are necessary.

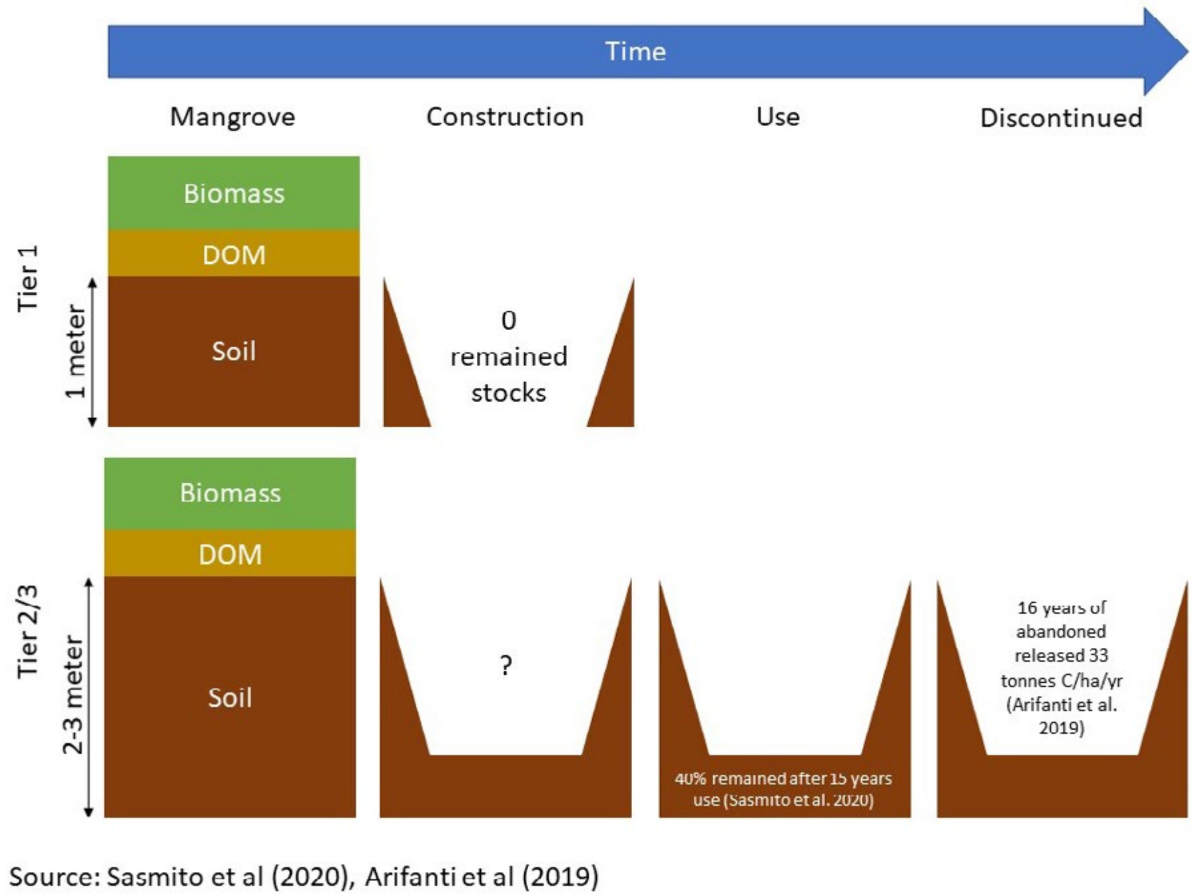


Figure 9: Possible dynamics projection of carbon stock pools and their portion of changes across different aquaculture sub-activities (construction, use, and discontinued) (Source: S. Sasmito)

DOM: Dead organic matter

5. Data sources

This section covers the range of data sources required to produce NGGI estimates for coastal wetlands and potential sources for Tier 1 data. National and global datasets are also explored in the context of filling data gaps and moving to higher Tier reporting of estimates.

Generating estimates for NGGIs typically relies on data from multiple sources and therefore can rely on collaboration between a range of stakeholders. Established institutional arrangements (see **Section 2.1**) can ensure data reliability and quality and ensure that collating and processing of existing data as well as generating new data though surveys or measurement campaigns are conducted efficiently and with minimal duplication of effort.

5.1 Default Data

When including for Coastal Wetlands in the NGGI for the first time, default emissions factors can be applied from the IPCC Guidelines where national factors do not exist. Countries can pursue the Tier 1 method in the absence of national level data and update their accounting method when country specific emission factors are developed in a stepwise approach.

The 2013 Wetlands Supplement provides Tier 1 default values for variables that are required to generate estimates from coastal wetland ecosystems (**Table 15: Variables required in the estimation of emissions and removals from coastal wetland ecosystems**) or in the context of reporting as coastal wetland activities (**Table 16**).

Table 15: Variables required in the estimation of emissions and removals from coastal wetland ecosystems

Coastal Wetland variable	2013 Wetlands Supplement default value
Carbon fraction of above-ground biomass (tonnes C (tonnes dry matter)$^{-1}$) in mangroves	Table 4.2
Above-ground biomass in mangroves (tonnes dry matter ha^{-1})	Table 4.3
Above-ground biomass growth in mangroves (tonnes dry matter ha^{-1} yr^{-1})	Table 4.4
Ratio of below-ground biomass to above-ground biomass (R) in mangroves	Table 4.5
Average density (D; tonnes m^{-3}) of mangrove wood	Table 4.6
Tier 1 default values for litter and dead wood carbon stocks in mangrove	Table 4.7
Summary of Tier 1 estimation of initial changes in carbon pools for extraction activities	Table 4.8

Coastal Wetland variable	2013 Wetlands Supplement default value
Ratio of below-ground biomass to above-ground biomass (R) for tidal marshes	Table 4.9
Ratio of below-ground biomass to above-ground biomass (R) for seagrass meadows	Table 4.10
Soil carbon stocks for mangroves, tidal marshes and seagrass meadows for extraction activities	Table 4.11
Annual emission factors associated with rewetting (EFRE) on aggregated organic and mineral soils (tonnes C ha^{-1} yr^{-1}) at initiation of vegetation reestablishment	Table 4.12
Annual emission factors associated with drainage (EFDR) on aggregated organic and mineral soils (tonnes C ha^{-1} yr^{-1})	Table 4.13
Emission factors for CH_4 (EFREWET) Tier 1 estimation of rewetted land previously vegetated by tidal marshes and mangroves	Table 4.14
Emission factor (EFF) for N_2O emission from aquaculture use in mangroves, tidal marshes and seagrass meadows	Table 4.15

Table 16: Summary table of default data for activities in coastal wetlands

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Forest management practices in mangroves	Mangrove	Biomass	2013 Wetlands Supplement	Section 4.2.1.1, **Tables 4.2-4.6**	Carbon fraction of above-ground biomass (tonnes dry matter), average above-ground biomass (tonnes dry matter ha^{-1}), mean annual above-ground biomass growth (tonnes dry matter ha^{-1} yr^{-1}), ratio of below-ground biomass to above-ground biomass and average wood density (tonnes m^{-3})	There have been advances in global mangrove biomass and growth (refer global data sources)
	Mangrove	Dead organic matter	2013 Wetlands Supplement	Section 4.2.1.2, **Table 4.7**	Litter and dead wood carbon stocks in mangroves (tonnes C ha^{-1})	
	Mangrove	Soil carbon	2013 Wetlands Supplement	Section 4.2.1.3. EF = 0	Soil CO_2 emissions and removals are assumed zero for forest management practices in mangroves.	There have been advances in global mangrove soil carbon stocks and sequestration (refer global data sources)

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Extraction (excavation to enable port, harbour and marina construction and filling or dredging to facilitate raising the elevation of land, and construction of aquaculture and salt production ponds)	Mangrove	Biomass	2013 Wetlands Supplement	Section 4.2.1.1, **Tables 4.2-4.6**	Above-ground biomass carbon stock, carbon fraction and below-ground to above-ground ratio, for different climate zones.	
	Tidal marsh	Biomass	2013 Wetlands Supplement	Section 4.2.2.1. No Tier 1 methodology. Default data (Table 4.9) given to calculate under Tier 2.	Ratio of below-ground biomass to above-ground biomass (Table 4.9) to be used in conjunction with the carbon fraction of dry matter alongside country-specific data on above-ground biomass carbon stock	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
	Seagrass	Biomass	2013 Wetlands Supplement	Section 4.2.2.1. No Tier 1 methodology. Default data (Table 4.10) given to calculate under Tier 2.	Ratio of below-ground biomass to above-ground biomass (Table 4.10) to be used in conjunction with the carbon fraction of dry matter alongside country-specific data on above-ground biomass carbon stock	
	Mangrove	Dead organic matter	2013 Wetlands Supplement	Section 4.2.2.2 refer to Section 4.2.1.2 **Table 4.7**	Litter and dead wood carbon stocks in mangroves (tonnes C ha^{-1}).	
	Tidal marsh and seagrass	Dead organic matter	2013 Wetlands Supplement	Section 4.2.2.2, **EF=0**	Carbon stocks in dead organic matter resulting from extraction activities are assumed zero in tidal marshes and seagrass meadows.	
	Mangrove, tidal marsh and seagrass	Soil carbon	2013 Wetlands Supplement	Section 4.2.2.3, **Table 4.11**	Soil carbon stocks across vegetation types and soil types (organic, mineral, aggregated organic and mineral) (tonnes ha^{-1}).	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Aquaculture and salt production ponds (use and discontinued)	Mangrove, tidal marsh and seagrass	Biomass, dead organic matter, soil carbon	2013 Wetlands Supplement	No Tier 1 methodology		
Rewetting, revegetation and creation	Mangrove	Biomass	2013 Wetlands Supplement	Section 4.2.3.1 >refer to Section 4.2.1.1, **Table 4.2-4.6**	Carbon fraction of above-ground biomass (t dry matter), average above-ground biomass (t dry matter ha^{-1}), mean annual above-ground biomass growth (tonnes dry matter ha^{-1} yr^{-1}), ratio of below-ground biomass to above-ground biomass and average wood density (tonnes m^{-3})	There have been advances in global mangrove biomass and growth (refer global data sources)
	Tidal marsh and seagrass	Biomass	2013 Wetlands Supplement	Section 4.2.3.1. No Tier 1 methodology. Default data (Tables 4.9 and 4.10) given to calculate under Tier 2.	Ratios of below-ground to above-ground biomass (Tables 4.9 and 4.10) to be used in conjunction with country-specific data on above-ground biomass stocks.	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
	Mangrove	Dead organic matter	2013 Wetlands Supplement	Section 4.2.3.2 >refer to Section 4.2.1.2, **Table 4.7**	Litter and dead wood carbon stocks in mangroves (tonnes C ha^{-1}).	
	Tidal marsh and seagrass	Dead organic matter	2013 Wetlands Supplement	Section 4.2.3.2. No Tier 1 methodology.	NA	
	Mangrove, tidal marsh and seagrass	Soil carbon	2013 Wetlands Supplement	Section 4.2.3.3, **Table 4.12**	Annual carbon sequestration on aggregated organic and mineral soils (tonnes C ha-1 yr-1) across vegetation types, applied at initiation of vegetation establishment. EF = 0 if no recolonization. EF > 0 when vegetation covers at least 10% of the area.	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Drainage in mangroves and tidal marshes	Mangrove	Biomass	2013 Wetlands Supplement	Section 4.2.4.1 > refer to Section 4.2.1.1, **Table 4.2-4.6**	Carbon fraction of above-ground biomass (tonnes dry matter), average above-ground biomass (tonnes dry matter ha^{-1}), mean annual above-ground biomass growth (tonnes dry matter ha^{-1} yr^{-1}), ratio of below-ground biomass to above-ground biomass, and average wood density (tonnes m^{-3}).	
	Tidal marsh	Biomass	2013 Wetlands Supplement	Section 4.2.4.1. **EF = 0**	For tidal marshes, increase in biomass stocks in a single year is assumed equal to biomass losses from mortality in that same year.	
	Mangrove	Dead organic matter	2013 Wetlands Supplement	Section 4.2.4.2 > refer to Section 4.2.3.2 > refer to Section 4.2.1.2 **Table 4.7**	Litter and dead wood carbon stocks in mangroves (tonnes C ha^{-1}).	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
	Tidal marsh	Dead organic matter	2013 Wetlands Supplement	Section 4.2.4.2. **EF = 0**	For tidal marshes, CO2 emissions and removals from change in biomass and dead organic matter pools are assumed zero.	
	Mangrove and tidal marsh	Soil carbon	2013 Wetlands Supplement	Section 4.2.4.3, **Table 4.13**	Annual carbon losses on drained aggregated organic and mineral soils (tonnes C ha-1 yr-1). Generic default emission factor, regardless of vegetation or soil type.	
Rewetted soils and created mangroves and tidal marshes	Mangrove and tidal marsh	CH_4 emissions	2013 Wetlands Supplement	Section 4.3.1.1, **Table 4.14**	Annual CH_4 emissions (kg CH_4 ha^{-1} y^{-1}) across salinity levels - freshwater and brackish water (<18ppt) and saline water (>18ppt). EF = 0 in saline tidal marshes and mangroves.	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Aquaculture use in mangroves, tidal marshes and seagrass meadows	Mangrove, tidal marsh and seagrass	N_2O emissions	2013 Wetlands Supplement	Section 4.3.2.1, **Table 4.15**	N_2O emissions from aquaculture ponds based on fish production (kg N_2O-N per kg fish produced). Default EF for 'in use' phase of aquaculture. EF = 0 in the construction and discontinued phases.	Emission factor developed for fish, and application to other species groups (e.g. shrimp) may introduce uncertainty.
Flooded Land Remaining Flooded Land	Reservoirs > 20 years	CH_4 emissions	2019 Wetlands Refinement	Section 7.3.1.2, **Table 7.9**	Annual CH_4 emissions (kg CH_4 ha^{-1} yr^{-1}) across climate zones.	Replaces default data on CH_4 emissions from flooded land remaining flooded land in 2006 Guidelines (Volume 4, Appendix 3, Table 3A.2)
	Other constructed waterbodies (freshwater or saline ponds used for agriculture, aquaculture or other activities, canals, and ditches)	CH_4 emissions	2019 Wetlands Refinement	Section 7.3.1.2, **Table 7.12**	Annual CH_4 emissions (kg CH_4 ha^{-1} yr^{-1}) across waterbody types and salinity levels - freshwater and brackish ponds (<18ppt) and saline ponds (>18 ppt).	

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
Land Converted to Flooded Land	Reservoirs =< 20 years old	CO_2 emissions from decay of organic matter	2019 Wetlands Refinement	Section 7.3.2.1, **Table 7.13**	Annual CO_2 emissions (tonnes CO_2-C ha^{-1} yr^{1}) across climate zones.	Table 7.14 provides scaling factor values that may be used with the Tier 2 method.
	Reservoirs =< 20 years old	CH_4 emissions	2019 Wetlands Refinement	Section 7.3.2.2, **Table 7.15**	Annual CH_4 emissions (kg CH_4 ha^{-1} yr^{-1}) across climate zones.	
	Other constructed waterbodies (ponds) created by damming	CO_2 emissions	2019 Wetlands Refinement	Section 7.3.2.1, **Table 7.13**	Annual CO_2 emissions (tonnes CO_2-C ha^{-1} yr^{1}) across climate zones.	
	Other constructed waterbodies (aquaculture ponds) created by excavation	CO_2 emissions	2019 Wetlands Supplement	Follow 2013 Wetlands Supplement - Section 4.2.1.1, **Tables 4.2-4.6** (biomass); Section 4.2.1.2, **Table 4.7** (dead organic matter); Section 4.2.2.3, **Table 4.11** (soil carbon)	Biomass, litter and dead wood and soil carbon stocks in mangroves (tonnes C ha^{-1}).	Insufficient information, use method for coastal wetlands converted to aquacultur ponds.

Activity	Vegetation type	Carbon pool or GHG	Document	Section and table number	Description of emission factor / default value	Data limitations
	Other constructed waterbodies (ditches, canals, farm ponds and aquaculture ponds)	CH_4 emissions	2019 Wetlands Refinement	Section 7.3.2.2 > refer to Section 7.3.1.2, **Table 7.12**	Annual CH_4 emissions (kg CH_4 ha^{-1} yr^{-1}) across waterbody types and salinity levels - freshwater and brackish ponds (<18ppt) and saline ponds (>18 ppt).	Insufficient information, use method for flooded land remaining flooded land

5.2 National data sources

When adopting national specific data to generate estimates, the IPCC states that it is *good practice* to assess existing data and to acquire national data in the following order of priority:

1. Use existing data:
    - national statistics (some case studies given in **Box 13 and Box 14**);
    - international statistics (see **Table 15: Variables required in the estimation of emissions and removals from coastal wetland ecosystems** and **Table 16: Summary table of default data for activities in coastal wetlands** for default data and examples given **Table 17**); and/or
    - other data sources including remote sensing and academia.
2. Engage in cooperation with data suppliers to provide tailored datasets from their information.
3. Modify existing datasets to meet the inventory requirements (e.g., where data is not collected on a calendar year basis convert to calendar year, adjust for different classifications of sources or fill gaps in territorial coverage).
4. Generate new data:
    - make measurements;
    - use census and survey data; and/or
    - coordinate with National Statistical Offices to undertake new surveys targeting inventory relevant sectors.

Use surrogate data (**Box 12**).

If the above approaches are unsuccessful and as a last resort, it is *good practice* to use expert judgement. It is *good practice* to focus resources on categories that have been identified as key categories (see **Section 3.5**). Improving data for less important categories can be done in later years.

National data sources may be available from a range of government agencies (national and subnational), non-government organisations and research institutions that can be used to estimate emissions from activities in coastal wetlands, such as surveying and mapping of coastal wetlands to identify activity data, and measurements of ecosystem carbon stocks and GHG emissions to determine emission factors. For improving national data, the Blue Carbon Manual (BCI, 2019) provides useful data collection advice for assessing carbon stocks in mangroves, tidal marshes, and seagrass meadows.

Box 12: Surrogate data related to Coastal Wetlands

Surrogate data is defined in the IPCC guidance as data that have a correlation with the data that they are replacing. The term 'proxy variable' is also often used in statistical literature. Surrogate data can be used where data may be unavailable or have gaps (e.g., if survey and sampling programmes have been infrequent or incomplete). For example, where a country has recent information on land-use change and have been successful in attributing drivers to the change, statistics relating to the driver can be used to fill gaps in the historical time series, where remotely sensed data are not available. An example of applying surrogate data in the context of developing coastal wetlands time series data is given in **Appendix A**.

In selecting and using surrogate data to estimate emissions or removals, it is *good practice* for countries to perform the following steps:

- Confirm and document the physical relationship between emissions/removals and the surrogate activity data.
- Confirm and document a statistically significant correlation between emissions/removals and the surrogate activity data.
- Using regression analysis, develop a country-specific factor relating emissions/removals to the surrogate data.

Further generic guidance is given in Section 5.3 of Chapter 5, Time Series Consistency of the 2006 IPCC Guidelines.

National data sources may be used in conjunction with default data (**Section**) and global data sources (**Section 5.3**) to enable the inclusion of Coastal Wetlands into NGGIs in a stepwise approach (see **Box 13**).

It is recognised that national and subnational data sources are collected and managed by various institutions within a country and data sharing will be key to enable integration and updating of datasets that can support the inclusion of Coastal Wetlands in NGGIs, as well as implementing conservation and restoration work at local scales (see **Box 14**). Establishment of working groups that span across institutions is recommended. Many REDD+ countries have had success in establish steering committees, and sub-working groups, to strengthen coordination and data sharing to ultimately improve quality of estimates.

Box 13: Combining tiered approaches to include mangroves and seagrasses in national greenhouse gas inventory (NGGI) in Fiji

While management and rehabilitation of mangroves is included in Fiji's Low Emissions Development Strategy, historically emission estimates from mangroves have not been included in the NGGI because of lack of coverage of mangrove mapping (Ministry of Economy, 2018). Over the last decade, Fiji has embarked on a program of consolidating and augmenting datasets within mangrove ecosystems, aiming to develop national data to support the voluntary reporting of REDD+ improved coverage and quality of NGGI reporting in the AFOLU sector.

With the aim of developing Approach 3 activity data and Tier 2 national specific GHG estimates within mangrove ecosystems, the Ministry of Forestry produced a spatially and temporally dense time series of wall-to-wall activity data for mangrove ecosystems and has incorporated mangrove ecosystems as a strata within the new multipurpose National Forest Inventory. These two nationally significant datasets will be combined with ecosystem specific data on mangrove ecosystem carbon stocks collected across different regions of Fiji, to support development of Tier 2 emission factors based on mangrove typology stratification, for all carbon pools (above-ground biomass, below-ground biomass, dead wood, and soil carbon) at both intact and damaged mangroves (Cameron et al., 2021) and different conversion types (Heider, 2013) including to settlement, which is the major anthropogenic driver of mangrove loss in Fiji.

As only limited sites were sampled within mangrove conversion, further data on other management activities is required to achieve Tier 2 reporting, particularly for estimating carbon sequestration following mangrove restoration. Whilst this nationally specific data will eventually become available following repeated National Forest Inventory data collection cycles, as an interim measure Fiji can apply Tier 1 emission factors (IPCC, 2014, 2019) and other global studies on mangrove carbon stocks (e.g., Hamilton & Friess, 2018; Kauffman et al., 2020; Sanderman et al., 2018; Sasmito et al., 2019) and sequestration rates (e.g., Xiong et al., 2019). See the Fiji demonstration in **Appendix B**.

Back of mangrove areas contain the freshwater tidal marshes and have not been sampled for carbon pools (Cameron et al., 2021); in this case Tier 1 emission factors and global data sources (e.g., Cheng et al., 2020) can be used to incorporate tidal marshes.

For Fiji to include seagrass meadows into the NGGI, improvements to seagrass mapping are required. The University of South Pacific is using drones to survey and map seagrass meadows, and the Ministry of Fisheries intends to continue this work. There are some global datasets on seagrass carbon stocks (Duarte et al., 2013; McLeod et al., 2011) that can be used to develop emission factors, in the absence of Tier 1 default data.

Box 14: Data sharing among government departments in Indonesia to integrate national and subnational data sources

Indonesia has included mangroves into its first FREL for deforestation and forest degradation (Government of Indonesia, 2016). Above-ground biomass of primary (undisturbed) and secondary (disturbed) mangrove forests were reported based on National Forest Inventory data (Krisnawati et al., 2012). Activity data of mangrove stratifications (primary and secondary) are also reported by the Government of Indonesia on an annual basis, accessible through the repository webpage (Ministry of Environment and Forestry, 2020). The Ministry of Environment and Forestry is the custodian of the national mangrove data and from 2021 plans to update the map at a scale of 1:25,000 every year for the entire country in collaboration with various government agencies. Previously the national mangrove map was produced and updated step by step for each region per year, so there are time gaps between regional maps. There are also challenges with detecting land-use change from current satellite imagery from visual interpretation, for example conversion of mangroves to shrimp aquaculture, which along with timber harvest are the main drivers of historical mangrove loss in Indonesia (Ilman et al., 2016). Furthermore, some mangrove areas in Indonesia overlap with peatlands, specifically in some parts of Eastern Sumatra, Kalimantan and Southern Papua (Gumbricht, 2017). High resolution satellite imagery would improve activity data, such as distinguishing aquaculture from other land-uses including bare land and abandoned aquaculture ponds (Arifanti, 2019; Cameron, Hutley, Friess, & Munksgaard, 2019). Recent work has used a machine learning-based classification approach of Landsat imagery in Google Earth Engine to map land cover changes, and a decision tree model to detect the human and natural drivers of mangrove loss, including conversion to aquaculture (Goldberg et al., 2020).

Research on national emission/removal factor data for mangroves in Indonesia has progressed over the past five years, covering all carbon pools (above-ground biomass, below-ground biomass, dead wood, and soil carbon) from primary mangroves (Murdiyarso et al., 2015), rehabilitated mangroves (Cameron, Hutley, Friess, & Brown, 2019; Sidik et al., 2019; Ulumuddin et al., 2021), and converted mangroves such as aquaculture and forest management (Arifanti, 2019; Sasmito et al., 2020) and is in the process of being integrated into the NGGI. While mangrove stratification in Indonesia is based on disturbance, there remains a lack of emission factor data from secondary mangroves, that have been impacted by vegetation extraction. Indonesia includes mangroves (above-ground biomass) in the current NGGI and will be including other mangrove carbon pools (below-ground biomass and soil carbon) based on research in the next reporting to the UNFCCC. Further improvements for inclusion of mangroves could be undertaken in a stepwise approach, including developing national emission factors for different land-uses in secondary mangroves. Seagrass meadows have not yet been included into NGGI because of the lack of time-series spatial mapping, and limited activity data (Unsworth, 2018). Some data on seagrass carbon stocks and sequestration from Indonesia are available (Rahayu et al., 2019; Wahyudi et al., 2020). The use of such data should be verified for reliability and consistency with the 2013 Wetlands Supplement. High-resolution satellite imagery would also improve mapping and activity data for seagrass meadows.

Box 14: Data sharing among government departments in Indonesia to integrate national and subnational data sources

Several government agencies in Indonesia are responsible for NGGI for different sectors (forestry, oceans, agriculture, energy) and undertake long-term monitoring as part of UNFCCC reporting using IPCC guidelines. For example, the Ministry of Environment and Forestry is responsible for REDD+ related reporting such as the submitted FREL. The Ministry of National Development Planning (Bappenas) is responsible for setting targets for emissions reduction of all sectors at national and subnational levels (e.g., Low Carbon Development Initiative). Government agencies collaborate to share and update data, enabling the inclusion of mangroves in national reporting. The Ministry of Environment and Forestry obtains the national mangrove data from the Geospatial Information Agency (national data center for Indonesia) and field verification is conducted in collaboration between the Ministry of Environment and Forestry, the Ministry of Maritime Affairs and Fisheries, the National Institute of Aeronautics and Space and Indonesia Institute of Science, Geospatial Information Agency, and Indonesian Institute of Science. Research is incorporated from the Research Development and Innovation Agency (Ministry of Environment and Forestry) and Blue Carbon Research (Ministry of Maritime Affairs and Fisheries) to derive national emission factors.

Under national planning policy, reporting of GHG emissions/removals will also be required at subnational (provincial) levels, despite challenges with local data availability and methodologies for estimating emissions. In 2019, the Ministry for Marine Affairs and Fisheries conducted a preliminary study with Bappenas to establish mangrove carbon emission baselines and conduct mitigation scenarios with mangrove conservation and rehabilitation projection (Susetyo Adi et al., 2020). This work is being refined with input from the Ministry of Environment and Forestry, however requires local data from the local governments. Overcoming challenges will require continued collaboration among national and local governments to share data and methods.

The Center for International Forestry Research (CIFOR) provides capacity building to government officials in Indonesia to improve the FREL and opportunity of implementing REDD+ at subnational level with jurisdictional approach, where blue carbon may be highlighted in places like East Kalimantan and West Papua. Several agencies, including CIFOR, is collaborating with the Ministry of Environment and Forestry to develop the new FREL, which will include peatland fires, non-CO2 gases from drained peatlands, emissions from dissolved organic carbon, and missing sinks in mangroves (e.g., regeneration and restored mangroves and peatlands), and will be used for crediting of REDD+ activities beyond 2020.

5.3 Global data sources

A range of global data sources (i.e. maps, datasets, databases) are available for coastal wetlands ( ) that can be used to assess the distribution of coastal wetlands, assist in the generation of activity data, inform emissions/removals estimates from land-use changes, or support verification or augmentation of national data sources.

Global synthesis studies on carbon stocks and/or sequestration rates for mangrove (e.g., Hamilton & Friess, 2018; Kauffman et al., 2020; Sanderman et al., 2018; Sasmito et al., 2019), tidal marsh (e.g., Cheng et al., 2020), and seagrass (e.g., Fourqurean et al., 2012) can be used to derive Tier 2 national emission factors for activities.

Global maps of coastal wetland cover (Bunting et al., 2018; Mcowen et al., 2017), drivers of mangrove loss (Goldberg et al., 2020) and extent of mangrove degradation (Worthington and Spalding, 2018) can be seen as complementary to national mapping capacity for estimating activity data. Some global data sources used on their own, in particular the seagrass cover mapping, are likely to be too inaccurate at the national level to use for NGGI estimates. However, these data sources can be combined with other surrogate data and expert judgement to provide a starting point for estimating spatial extent.

Whether adopting global datasets as the primary data source for activity data or as an auxiliary data source to stratify or validate national data it is recommended to consider if the global product (GFOI, 2020)[23]:

Aligns with the ongoing temporal reporting needs of NGGI (i.e., are the global datasets static maps of a one-time period or dynamic maps showing multiple time periods).

- Can be used to generate time series consistent land-use change statistics.
- Covers the required geographical extent of the target land-use, land cover category.
- Classifies land areas and area changes by applying a land cover definition that closely resembles national land cover definitions and that any refinements can be made to report land-use where necessary to enable activity based estimates to be generated.
- Reports accuracy of the product such that uncertainty estimates can be made consistent with IPCC guidelines, and the reported level of accuracy meets national requirements.

Where global datasets are utilised, national validation using reference data points will enhance confidence in the product. Documenting validation processes (for both national and global datasets) is important for transparency in reporting (see **Section 6.5**).

23 For more detail on considerations related to adopting spatial global datasets refer to GFOI, 2020; Chapter 3

Table 17: Global data sources for coastal wetlands

Coastal wetland	Type of data	Link	Reference / comments
Wetlands	Freely available remote-sensing service using optical and radar satellite data to assist countries with mapping and monitoring changes in their wetlands.	Satellite-based Wetland Observation Service https://www.swos-service.eu/	Weise et al. (2020)
Wetlands	Global extent of wetlands (inland and coastal) derived from remote sensing analysis.	Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) Global Wetlands Map https://www.cifor.org/global-wetlands/	(SWAMP)
Wetlands	Carbon stocks and GHG effluxes database for global mangrove and peatlands	SWAMP Database Management https://www.cifor.org/swamp/database/database-management/	(SWAMP)
Lakes and Wetlands	Global extent of large lakes and reservoirs, smaller water bodies and wetlands.	Global Lakes and Wetlands Database https://www.worldwildlife.org/publications/global-lakes-and-wetlands-database-lakes-and-wetlands-grid-level-3	Lehner and Döll (2004)
Coastal wetlands	The network provides database on blue carbon inventories from coastal wetlands.	Coastal Carbon Data Clearinghouse https://serc.si.edu/coastalcarbon/data	Coastal Carbo Researc Coordination Network
Mangrove	Global mangrove cover – time series	Global Mangrove Watch 1996-2016 version 2.0 https://data.unep-wcmc.org/datasets/45 or https://www.globalmangrovewatch.org/	Bunting et al. (2018)
	Global mangrove coastal typology map	https://www.nature.com/articles/s41598-020-71194-5	Worthington, zu Ermgassen et al. (2020)
	Global above-ground biomass	https://daac.ornl.gov/CMS/guides/CMS_Global_Map_Mangrove_Canopy.html or https://mangrovescience.earthengine.app/view/mangroveheightandbiomass	Simard (2019)

Coastal wetland	Type of data	Link	Reference / comments
	Global soil carbon	https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi%3A10.7910/DVN/OCYUIT	Sanderman et al. (2018)
	Regional above-ground biomass	https://doi.org/10.1111/conl.12060	Hutchison et al. (2014)
	Regional above-ground wood production	https://doi.org/10.5061/dryad.s90b488	Xion et al. (2019)
	Regional soil carbon stocks	https://doi.org/10.1038/nclimate3326	Atwood et al. (2017)
	Regional above-ground biomass, below-ground biomass, and soil carbon stocks	https://doi.org/10.1002/ecm.1405; https://doi.org/10.1038/s41558-018-0090-4	Kauffman et al. (2020); Hamilton and Friess (2018)
	Regional carbon stocks and GHG effluxes for anthropogenic land use and land cover changes	https://doi.org/10.1111/gcb.14774	Sasmito et al. (2019)
	Activity data for mangrove degradation	Global mangrove restoration potential http://maps.oceanwealth.org/mangrove-restoration/	Worthington and Spalding (2018)
	Activity data for mangrove loss (natural and anthropogenic drivers)	CMS: Global Mangrove Loss Extent, Land Cover Change, and Loss Drivers 2000-2016 https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1768	Goldberg et al. (2020)
	Mapping methods	The Google Earth Engine Mangrove Mapping Methodology (GEEMMM) https://doi.org/10.3390/rs12223758	Yanch et al. (2020)
Tida marsh	Global tidal marsh cover	Global distribution of saltmarshes version 6.0 https://data.unep-wcmc.org/datasets/43	Mcowen et al. (2017)
	Regional soil carbon sequestration rates	https://doi.org/10.1007/s11769-020-1122-3	Cheng et al. (2020)
Seagrass	Global seagrass cover	Global distribution of seagrasses version 7.0 https://data.unep-wcmc.org/datasets/7	UNEP-WCM (2020)

Coastal wetland	Type of data	Link	Reference / comments
	Regional biomass and soil carbon	https://doi.org/10.1038/ngeo1477	Fourqurean et al. (2012)
Aquaculture	Fish production for coastal and marine aquaculture	FAO Fisheries and Aquaculture FishStats http://www.fao.org/fishery/statistics/global-production/en and country profiles http://www.fao.org/fishery/countryprofiles/search/en	(FAO, 2019)

For transparency, it is good practice to document the details of the data and emission factors applied in generating estimates of Coastal Wetlands. When assessing if data are fit for purpose, it is recommended that the data documentation requirements listed in **Table 19** are considered.

6. Measurement, reporting and verification

Measurable, reportable, and verifiable (MRV) is a concept identified by UNFCCC as integral to all climate mitigation efforts[24]. MRV is necessary for accurate tracking of GHG emission reductions, the issuance of carbon credits at the project level, and especially for improving credibility regarding climate mitigation actions to achieve Nationally Determined Contributions. MRV comprises a series of steps leading to greater transparency, accuracy, completeness, consistency and comparability (**Box 15**) in NGGI reporting and mitigation actions as well as in individual, project-level (subnational) mitigation efforts. These steps, discussed in this section in the context of coastal wetland ecosystems, include:

- Uncertainty estimation
- Completeness
- Time series consistency
- Quality assurance and quality control
- reporting and documentation.

Box 15: TACCC principles - transparency accuracy, completeness, consistency and comparability

National Greenhouse Gas Inventories (NGGIs) are to be prepared in accordance with the TACCC principles of Transparency, Accuracy, Completeness, Comparability, Consistency.

Transparency

- Assumptions and methodologies are clearly explained and documented to facilitate replication and assessment.
- If documentation is not provided, there is no way to demonstrate that any of the other principles has been met.

Accuracy

- Relative measure of the exactness of emission/removal estimates.
- Estimates must be systematically neither over nor under true emissions/removals, as far as can be judged according to the available data and information.
- Uncertainties must be reduced as far as practicable.
- Appropriate methodologies must be used, in accordance with IPCC guidelines.

24 Bali Action Plan UNFCCC Decision 1/CP.13 in FCCC/CP/2007/6/Add.1

Box 15: TACCC principles - transparency accuracy, completeness, consistency and comparability

- **Consistency**
- Inventory is internally consistent in all its elements with inventories from previous years.
- Same methodologies for the base year and all subsequent years.
- Consistent datasets to estimate emissions and removals from sources/sinks.
- When stepwise improvements are made to methodologies or datasets then the entire time series is recalculated to maintain internal consistency.

Comparability

- Estimates must be comparable among Parties which can be achieved by following the IPCC guidance and guidelines.

Completeness

- All sources/sinks and gases included in the IPCC Guidelines should be included or explanations provided for any exclusions.
- Full geographic coverage of sources/sinks of a Party are expected in NGGIs.

In the absence of national data for reporting key categories within Coastal Wetlands, it is preferable to include Tier 1 estimates using methods and default values from the 2013 Wetlands Supplement to meet the completeness principle.

6.1 Uncertainty estimation

All estimates within the NGGI should be reported with associated uncertainty. Uncertainty is estimated by combining quantifiable sources of uncertainty (e.g., field measurement errors, remotely sensed data classification inaccuracies, missing or incomplete time series data, model inaccuracies).

The IPCC notes three steps in the process of developing uncertainty related to NGGI estimates:

1. Identification of the sources of uncertainty.
2. Estimation of uncertainty for individual variables.
3. The combination of individual variable uncertainties into total uncertainty estimates of emissions or removals for a land-use category for a geographic area.

Uncertainties particular to coastal wetland ecosystems include variation of above-ground biomass by mangrove or seagrass species, forest age, tide height, soil fertility, salinity of flood waters, and flood frequency and interannual variation of vegetation production (IPCC, 2014). Carbon stocks and changes within seagrass meadows are harder to measure accurately compared with mangroves and tidal marshes. Additionally, soil carbon may be imprecisely estimated due to variations in soil depth and carbon content resulting in higher levels of uncertainty in this pool. Therefore, higher reported uncertainties for these ecosystems should be expected in monitoring efforts over time.

It is *good practice* to use uncertainty estimates reported by or derived from the same data sources used for the emissions/removals estimates. For Tier 1 estimates, use the uncertainties given in Tier 1 default variables tables provided by the IPCC (**Table 16: Summary table of default data for activities in coastal wetlands**). For Tier 2, the data sources of the country- or ecosystem-specific parameters would provide the most appropriate uncertainty estimates[25]. The IPCC states that it is *good practice* to reduce uncertainties as far as practicable. It is recommended to focus on uncertainty reduction within identified key categories (and any subcategories), and in the context of continuous improvement over time, to make best use of available resources.

The IPCC provides extensive guidance for the combination of individual variable uncertainties into total uncertainty estimates using either the basic propagation of error approach or the more advance Monte Carlo analysis approach.

It is recommended to focus on uncertainty reduction within identified key categories (and any subcategories), and in the context of continuous improvement over time, to make best use of available resources. Recommendations for reducing uncertainty in coastal wetland ecosystems include:

- More detailed stratification of land by drainage, management systems, vegetation composition, and previous land-use history can improve confidence intervals around data collected.
- Quantification of the effects of coastal grassland management, including grazing, fire, liming, and fertilisation can improve emissions estimates.

6.2 Completeness

Complete NGGIs include estimates of emissions and removals from the sources and sinks for which methodological guidance is provided in the 2006 IPCC Guidelines and the 2013 Wetlands Supplement unless the specific sources and sinks do not occur on the national territory.

When countries are considering the inclusion of Coastal Wetlands for completeness it is *good practice* to include all managed areas of mangrove, tidal marshes and seagrasses using Tier 1 methods, and ideally higher Tiers where activities within these ecosystems are considered key categories.

In circumstances where emissions/removals from Coastal Wetlands are relevant to a country but are not reported it is *good practice* to provide justification as to why it has been excluded from reporting (see **Section 6.5 Reporting and documentation**). This assists in transparency within the NGGI.

In the absence of national data for reporting key categories within Coastal Wetlands, it is preferable to include Tier 1 estimates using methods and default values from the 2013 Wetlands Supplement to meet the completeness principle of the IPCC.

25 In the absence of country- or ecosystem-specific uncertainty estimates, it is possible to use published uncertainty estimates for similar ecosystems or circumstances. The 2013 Wetlands Supplement presents a list of examples of wetlands and drained soils with published estimates of uncertainties of parameters used in estimating greenhouse gas emissions and removals (Table 7.2). These published uncertainty estimates can also provide useful data to check country- or ecosystem-specific uncertainty estimates.

6.3 Time series consistency

Time series consistency[26] means the inventory, in any particular year, is internally consistent in all its elements with inventories from previous years in that:

- The same methodologies are applied for the base year and all subsequent years.
- Consistent datasets to estimate emissions and removals from sources/sinks are year are used for each inventory period.
- When stepwise improvements are made to methodologies or datasets the entire time series is recalculated to maintain internal consistency.

NGGI methods are to remain consistent for an entire time series so that each year in the time series can be compared with other years. This provides countries with information to assess temporal trends in GHG emissions and removals and the effectiveness of emissions reduction measures. Time series consistency ensures that any changes (increases or reductions) in GHG emissions are a result of real phenomena in the environment, not the result of:

- Changes and refinements to methodological changes and refinements.
- Addition of new categories.
- Data gaps.
- Correction of errors.

Most countries will experience gaps in activity data in coastal wetlands which make completion of the inventory back through time very challenging. There are methods outlined in the IPCC guidance for filling data gaps in the time series. In particular, Volume 1, Chapter 5 of the 2006 IPCC Guidelines and its 2019 Wetlands Refinement, and **Box 16** below provide details of techniques to overcome incomplete time series data.

Adopting the 2013 Wetlands Supplement to include Coastal Wetlands in NGGIs will trigger the requirement for the recalculation of results from previous inventory to maintain time series consistency. This is due to changes in the methods for soil organic matter and refinement of the subcategories within land-use categories between the 2006 IPCC Guidelines and the 2013 Wetlands Supplement.

6.3.1 Recalculations due to methodological changes and refinements

Both methodological changes and refinements over time are an essential part of improving inventory quality. It is *good practice* to change or refine methods when:

- Available data have changed and that facilitate improvements in methods.
- A previously used method is not consistent with the IPCC Guidelines for that category (this is the case for Coastal Wetlands as they are a new guidance from the 2013 Wetlands Supplement.
- The previously used method is insufficient to reflect mitigation activities in a transparent manner.

26 The IPCC guidance provided in the 2006 Guidelines relating to time series consistency has been extensively updated and new guidance presented in the 2019 Refinement and it is recommended that this be the source, in particular Volume 1, Chapter 5 be applied in relation to ensuring time series consistency.

- The capacity for inventory preparation has increased enabling the possibility to adopt changes or refinements to methods to produce more accurate, complete and transparent estimates, particularly for key categories.
- New inventory methods become available. Remote-sensing technology improvements are most likely to influence such methodology changes or refinements related to coastal wetland ecosystems.
- Availability of new emission factors in the IPCC Guidelines that could be different from previous IPCC Guidelines.

6.3.2 Adding new categories

The addition to the inventory of a new category or subcategory such as Coastal Wetlands to a NGGI requires the calculation of an entire time series, and estimates should be included in the inventory from the year emissions or removals start to occur in the country.

Additionally, applying the 2013 Wetlands Supplement to include Coastal Wetlands in NGGIs will require the recalculation of results from previous inventory years to produce a consistent time series due to substantial changes to the 2006 IPCC Guidelines methods for soil organic matter and refinement of the subcategories within all land-use categories (IPCC, 2014).

A country should make every effort to use the same method and datasets for each year. It may be difficult to collect data for previous years, particularly for tidal marshes and seagrasses in the Coastal Wetland subcategory. The IPCC presents a number of splicing techniques to deal with changes in data availability and data gaps to and guidance on selecting the most appropriate technique[27] to construct a consistent time series (see **Box 16**).

6.3.3 Data gaps

Coastal wetland ecosystems are likely to have national data gaps, making it challenging to develop a complete and consistent time series. Both periodically collected data and gaps in availability are common in environmental statistics or natural resource datasets upon which coastal wetlands emissions and removals typically rely.

Periodic datasets such as national forest inventories, may not cover the entire country on an annual basis but are rather carried out at intervals (e.g. every 5 or 10 years), or region-by-region. When data are available less frequently than annual, the following issues arise:

- Estimates need to be updated each time new data become available, and the years between the available data need to be recalculated.
- Producing inventories for years after the last available data point and before new data are available requires extrapolation based on available data, and then recalculation when new data become available.

Changes in data availability or gaps in data typically arise from research programs or short-term funded ecosystem monitoring programs or from persistent cloud cover in remotely sensed data. Such data gaps present increased challenges as opportunities to recalculate the estimate using better data are unlikely (see **Box 16**). Surrogate data (see **Box 12**) can play a role in addressing data gaps.

27 See the Volume 1, Chapter 5, Section 5.3.3.6 of the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

6.3.4 Correction of errors

Correction of errors identified through QA/QC processes although not strictly a methodological change or refinement may also need to be implemented in the with time series consistency in mind (i.e., any errors found should be corrected where they occur in the entire time series).

Box 16: How to address data gaps in and historical time series to initially incorporate Coastal Wetlands in National Greenhouse Gas Inventories

The choice of splicing technique involves expert judgement and depends on an expert assessment of the volatility of emissions trend, the availability of data for two overlapping methods, the adequacy and availability of surrogate datasets, and the number of years of missing data. If time series data back to 1990 are unavailable, it is suggested that surrogate data be used, derived from statistical reports/databases containing information on temporal changes in proxy factors such as human population density, port or marina development, port revenue, shipping tonnage, and commodity exports.

If time series data back to 1990 are unavailable, it is suggested that surrogate data be used, derived from statistical reports/databases containing information on temporal changes in proxy factors such as human population density, port or marina development, port revenue, shipping tonnage, and commodity exports.

6.4 Quality assurance and quality control

Quality assurance and quality control are procedures to improve the accuracy, transparency, consistency, comparability, and completeness of inventories. Effectively implemented quality procedures can reduce uncertainties of greenhouse gas inventories (IPCC, 2014).

The IPCC guidance has a number of useful checklists as guide for generic quality checks related to calculations, data processing, completeness, and documentation that are applicable to all inventory source and sink categories[28]. The 2013 Wetlands Supplement also lists some useful considerations as a summary of the longer checklist:

- Double-check outlying values against data sources.
- Check final results against previous years and published values.
- Compare inventories with results from similar ecosystems in other countries.
- Conduct an area-balance for land-use category areas and, when applicable, a mass-balance for greenhouse gas emissions and removals.
- Develop automated data control procedures.
- Prioritise key categories for more extensive quality assurance and quality control.

28 Volume 1; Chapter 6 covers quality assurance and quality control in a generic sense as it relates to National Greenhouse Gas Inventories. Annex 6A.1 covers both generic and category specific quality control checklists.

It is probable that most countries will initially rely on default emission factors (see **Section 5.1 Default data**) and globally available datasets (see **Section 5.3 Global data sources**) to initially report most coastal wetland ecosystems and activities. In this case, quality control checks should still be conducted (see **Table 18: Useful quality control checks in applying default emission factors and global datasets applied in estimates within Coastal Wetlands** for some suggestions). Documentation of such checks are recommended to support transparency in reporting (see **Table 19**).

Table 18: Useful quality control checks in applying default emission factors and global datasets applied in estimates within Coastal Wetlands

Element	Quality Control Check	Selection Checks	Suggested Documentation
Emission Factors[1]	Assess representativeness of emission factors, given national circumstances and analogous emissions data.	If applying default emission factors, ensure the Domain and Region represent national conditions. Where national values are available ensure that they have been developed in similar ecosystems or have national relevance.	Full citation of reference. Description of geographical representation and relationship to national conditions.
	Compare to alternative factors.	Where national values are applied, a comparison with IPCC default values, global datasets or values applied by neighbouring countries can be useful.	Explain rationale for selection.
	Search for options for more representative data.	In depth literature reviews and liaison with neighbouring countries or those with similar conditions can provide insights into representatives.	Describe the search conducted to arrive at selected emission factor.

Element	Quality Control Check	Selection Checks	Suggested Documentation
Activity Data[2]	Check historical trends.	Make use of all available global and national datasets to 'sense' check the change data.	Describe how the historical trends align with expected national trends based on other national and global datasets and local knowledge of historical land-use/land cover change.
	Compare multiple reference sources.		Document the datasets considered and rationale behind selection.
	Check applicability of data.	If using global datasets check that the land-use/ land cover definitions align with national definitions. Check that there are no inconsistencies or overlap with other terrestrial land cover change datasets.	Document the land cover definition applied in the datasets and explain how they align with national definitions. Where multiple activity data sources are used document how double counting of lands is avoided.
	Check methodology for filling in time series for data that are not available annually.	Assess that the dataset is (or can be) temporally consistent with the NGGI reporting requirements.	Provide explanation how data is applied to generate consistent time series.

1 See Table 16: Summary table of default data for activities in coastal wetlands in Section 5.1 Default data for full list of Coastal Wetland IPCC default emission factors.

2 In many cases global datasets may be required for activity data related to Coastal Wetlands

6.5 Reporting and documentation

Reporting of Coastal Wetlands involves combining guidance from both the 2013 Wetlands Supplement and the 2006 IPCC Guidelines. Chapter 8 in Volume 1 of the 2006 IPCC Guidelines provides general guidance on reporting complete, consistent, and transparent NGGIs. Category-specific guidance outlining documentation requirements relevant to Wetlands is provided in Chapter 4 and 7. The 2013 Wetlands Supplement lists information and documentation specific to reporting of Coastal Wetlands in Chapters 4 and more generally for Wetlands in Chapter 7.

The guidelines related to documentation and some considerations to include in information to meet good practice are summarised in **Table 19: Recommended information and associated considerations to include with reporting.** The information presented is not exhaustive and countries are advised to include as much information as possible to enhance transparency.

Table 19: Recommended information and associated considerations to include with reporting

Information to Document	Considerations
Methods for identifying activities and land areas.	Document your national land representation decisions, land-use/land cover definitions, stratification protocols, datasets, and auxiliary datasets.
Classification of activities and land areas.	Describe how activity data is generated from the datasets and any attribution rules applied to classify activities and land-use changes through time to ensure consistent representation of lands that meet national definitions.
Indication if emissions/ removals are associated with areas that are not included in the total land areas.	Provide explanation of land representation, including seaward limits and how this relates to seagrass emission/removal estimates.
Stratification protocols	Disaggregated activity data and emission factors / parameters used by climate regime (temperature, precipitation), nutrient status, ecosystem type and activity/system, as relevant, and the level at which the emissions/removals are estimated. A detailed description of the stratification applied and the associated activity data and emission factors will assist with communication of methodological decisions. A clear description of disaggregation in the inventory, and for example REDD+ if relevant, will assist in transparency. Documenting the activities reported as occurring in Coastal Wetlands can assist in identifying and justifying the selection of applied emission factors.
Explanation of how completeness has been assessed and double counting avoided.	Combining a country-specific method to estimate emissions/ removals from below-ground biomass, litter, or understory (vegetation such as mosses) with default emission factors for drainage and rewetting, which integrate all carbon fluxes from the soil and the above-ground and below-ground vegetation components other than trees, could double-count the respective emissions/removals. Additionally, If the stock change method is used for a specific category/activity for estimation of CO_2 emissions/removals from soils and the default emission factors are used for dissolved organic carbon, the latter emissions may be included in the stock change estimate.

Information to Document	Considerations
Details of country-specific emission factors applied.	When country-specific emission factors or other parameters are used, documentation and references justifying their use enhances transparency including demonstrating that the adoption of country-specific emission factors / parameters result in an improvement in the accuracy of the estimates.
Results of key category analysis as the basis for explaining methodological choice for each category.	List the criteria by which each category was identified as key (e.g., level, trend, or qualitative), and the method used to conduct the quantitative key category analysis (e.g., Approach 1 or Approach 2).
Quality control and archiving procedures.	Documenting all system procedures, for example in a series of standard operating procedures, assists in ensuring consistency in developing estimates each inventory period. Such documentation also assists in maintaining institutional knowledge. Evidence of implementation of the procedures, such as completed QC checklists, also assists in transparent reporting and can provide increased confidence in the estimates during technical review. The 2006 IPCC Guidelines (Volume 1, Chapter 6, Annex 6A.1) include a number of useful generic checklists that can be applied at the subcategory level. Countries are also free to develop their own specific checklists to suit their needs.
Explanation of any data gaps.	For data gaps, it is good practice to clearly report where an inventory presents measured or monitored results and where it presents model output. Data gaps in inventory estimations from the AFLOU sector are common. Countries should fully document the splicing techniques applied to address such gaps (see **Section 6.3 Time series consistency; Box 16**).

7. Key resource list

Resources	Relevance to this document
2006 IPCC Guidelines for National Greenhouse Gas Inventories	Global standard guidance document for all sectors GHG inventories and reporting at national scale. The Volume 4 Agriculture, Forestry and Other Land-use (AFOLU) is one of the most relevant sections for land-based GHG inventory such as blue carbon ecosystems.
2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands	The guideline provides Tier 1 default emissions factors for activities aggregated by ecosystems (mangrove, tidal marsh, seagrass meadow).
2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands	The guidelines provide definition and approach to estimate emissions/removals from Flooded Land Representation.
Guidelines for Blue Carbon and Nationally Determined Contributions	The Blue Carbon and Nationally Determined Contributions: Guidelines on Enhanced Action provides a guide on how countries may include blue carbon in their Nationally Determined Contributions.
GFOI Methods and Guidance Document Edition 3.0	GFOI (2020) provides approaches to estimate Forest Land GHG emissions/removals through the integration of remote sensing and ground-based observations.
Blue Carbon Manual	The manual provides a compilation field guideline for measuring, assessing, and analysing coastal blue carbon for mangrove, seagrass, and tidal marsh.
Blue Carbon Primer	This book is a comprehensive and current compendium of the state of the science, the state of maps and mapping protocols, and the state of policy incentives (including economic valuation of blue carbon), with additional sections on operationalising blue carbon projects and seven case studies with global relevance.

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Scenario 1: Time series land-use transitions in mangroves

Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7
Mangrove	**Converted to degraded mangrove**	**Degraded mangrove**	**Converted to aquaculture pond (construction)**	**Aquaculture pond (use)**	**Aquaculture pond (discontinued)**	**Regenerating mangrove <20 year(>20 years see Time 1)**
Land representation						
If mangrove is considered Managed Land and meet national forest definition, report as Forest Land remaining Forest Land. Report mangrove as Wetlands-Coastal wetlands remaining Wetlands-Coastal wetlands if mangrove height doesn't meet national forest definition (e.g. dwarf or scrub mangrove).	If degradation is due to a management activity, report as Forest Land remaining Forest Land; or Wetlands-Coastal wetlands remaining Wetlands-Coastal wetlands.	Report as Forest Land remaining Forest Land; or Wetlands-Coastal wetlands remaining Wetlands-Coastal wetlands.	Report as Forest Land converted to Wetlands-Coastal wetlands (<20 years) or Wetlands-Coastal wetlands converted to Wetlands Flooded Land.	Report as Wetlands - Flooded Lands remaining Wetlands-Flooded Land.	Report as Wetlands -Flooded Lands remaining Wetlands-Flooded Land.	Report as Wetlands – Flooded lands converted to Wetlands-Coastal wetlands or Wetlands – Flooded lands converted to Forest Land.
Estimating carbon emissions and removals from *key* categories						
Use carbon stock change for AGB, BGB, DOM and soil carbon pools. Tier 1 values available for all pools. Annual biomass growth and soil carbon accumulation rates canalso be used for calculating CO_2 removals.	Forest management activities. Tier 1 method for CO_2 emissions from wood extraction[2].	Forest management activities. Tier 1 method for CO_2 emissions from wood extraction.	Estimate CO_2 emissions associated with biomass removal and excavation of soil carbon during pond construction.	Estimate emissions of N_2O (based on yield[1]) and CH_4 (based on salinity) associated with aquaculture use.	Estimate CH_4 emissions based on salinity using Tier 1 factors.	Estimate CO_2 emissions and removals associated with "rewetting" – at Tier 1 can include AGB, BGB, DOM, and soil carbon stock pools. Tier 1 factors also provide biomass growth and soilcarbon accumulation. Estimate CH_4 emissions based on salinity.

Time 1	Time 2	Time 3	Time 4	Time 5	Time 6	Time 7
Mangrove	**Converted to degraded mangrove**	**Degraded mangrove**	**Converted to aquaculture pond (construction)**	**Aquaculture pond (use)**	**Aquaculture pond (discontinued)**	**Regenerating mangrove <20 year(>20 years see Time 1)**
Estimating carbon emissions and removals from *key* categories						
If considered Unmanaged Land, no emissions / removals estimated and reported.	See Indonesia casestudy		Tier 1 methods are available to estimate emissions of N_2O (based on yield[1]) and CH_4 (based on salinity) associated with aquaculture use; aquaculture considered managedlands – see above.	Aquaculture considered managedlands – see above.		If unmanaged reforestation, then no emissions/removals estimated and reported.
Information and data gaps (Opportunities for Improvements)						
Collect Tier 2/3 factors for all carbon stocks pools. Define mangrove soil depths and stratification, whether mineral or organic soils. For mangrove mineral soils, carbon stock change is suggested to estimate emissions/ removals. For mangrove organic soils, emissions / removals estimate should use gain-loss approach. Tier 1 factors provide soil carbon stocks up to 1 meter only.	Collect data to develop Tier 2/3 factors (all carbon stock pools) for forest management activities.	Collect data to develop Tier 2/3 factors (all carbon stock pools) for forest management activities.	Collect data to develop Tier 2/3 factors such as the depth of pond or excavated soils. Define mangrove soil stratification, whether mineral or organic soils.	Collect data to develop Tier 2/3 factors for non-CO_2 emissions (N_2O and CH_4), and soil carbon stock change (e.g., soil carbon accumulation).	Collect data to develop Tier 2/3 factors for non-CO_2 emissions (CH_4), and soil carbon stock change (e.g., soil carbon accumulation).	Collect Tier 2/3 for biomass growth, non-CO_2 emissions (CH_4), and and soil carbon stock change (e.g., soil carbon accumulation).

1 assume that aquaculture (use) emissions may be reported under agriculture sector

2 would need field data to estimate wood extraction

Scenario 2: Time series land-use transitions in seagrass meadows

Time 1	Time 2	Time 3	Time 4	Time 5	Time 6
Seagrass	**Seagrass remains**	**Seagrass dredged to unvegetated sediment**	**Unvegetated sediment**	**Converted to seagrass**	**Seagrass remaining Seagrass**
Land representation					
If considered Managed Land report as Wetlands – Coastal wetlands	If considered Managed Land report as Wetlands – Coastal wetlands remaining Wetlands- Coastal wetlands	Report as Wetlands – Coastal wetlands converted to Wetlands- Other Coastal wetlands	Report as Wetlands- Other Coastal wetlands remaining Wetlands- Other Coastal wetlands	Report as Wetlands- Other Coastal wetlands converted to Coastal wetlands	Report as Coastal wetlands remaining Coastal wetlands
Estimating carbon emissions and removals from *key* categories					
Soil carbon pool available at Tier 1; calculate CH_4 emissions based on salinity.	Soil carbon pool available at Tier 1.	Estimate CO_2 emissions associated with excavation of soil carbon in Year 1, Tier 1; account for CO_2 emissions from biomass loss; calculate CH_4 emissions based on salinity.	Estimate emissions / removals CO_2 associated with unvegetated sediment (Tier 2/3); calculate CH_4 emissions based on salinity.	Estimate CO_2 emissions / removals (Tier 2/3); assume that biomass stock occurs in the first year; assume soil C accumulation begins in first year; estimate CO_2 emissions with biomass change; no distinction between mineral and organic soils; calculate CH_4 emissions based on salinity.	Estimate CO_2 emissions and removals (Tier 2/3); calculate CH_4 emissions based on salinity.
If considered Unmanaged Land, no emissions / removals estimated and reported.		Estimate emissions / removals associated with unvegetated sediment (Tier 2/3).			

1 Tier 1 values for root to shoot rations are available in the 2013 Wetlands Supplement (Table 4.9)