METHODOLOGY

SUSTAINABLE MANAGEMENT OF MANGROVES

SDG 13

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CONTACT DETAILS
The Gold Standard Foundation
International Environment House 2
Chemin de Balexert 7-9
1219 Châtelaine Geneva, Switzerland
Tel +41 22 788 70 80
Email help@goldstandard.org

SUMMARY

The methodology is applicable globally.

Mangrove systems have unique aspects, so they are considered separately from a conventional afforestation/reforestation (A/R) activity. Given the often difficult accessibility of mangrove systems, the methodology includes the option to combine in situ measurements of aboveground tree biomass with remote sensing. The following four approaches are allowed for accounting:

1. Remote sensing: Regression analysis between on-site biomass measurements and remote sensing biomass estimation
2. Field measurement: In situ measurements and site-specific models
3. Models: Local or regional datasets and/or models (only with validation against in situ measurements)
4. Default values: Based on Intergovernmental Panel on Climate Change (IPCC) default values (only with validation against in situ measurements)

Apart from aboveground tree biomass, carbon pools accounted for include belowground tree biomass and soil organic matter. The inclusion of aboveground and

belowground non-tree biomass is mandatory for the baseline assessment but is optional for the estimation of carbon removals.

ACKNOWLEDGEMENT

This methodology was co-developed by the Gold Standard Secretariat and FORLIANCE GmbH.

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1| INTRODUCTION

1.1.1 | The following table describes the key information for the application of the methodology.

Table 1. Key information

Typical mitigation activity (project) type	Activities that involve plantation of mangroves in areas that historically supported mangrove ecosystems. The terms 'Mitigation Activity', 'Activity' and 'Project' refer to project activity and are used interchangeably.
Activity Requirement	Blue Carbon and Freshwater Wetlands
Mitigation activity (project) type	Blue Carbon
Sectoral scope	Sectoral scope(s): SS 14
Applicable Gold Standard for Global Goals (GS4GG) products	☒ Gold Standard Verified Emissions Reduction (GSVERs) ☒ Certified impact statement
Geographical applicability	Global
Applicable activity (project) scale	☒ Micro scale ☒ Small scale ☒ Large scale An activity can claim emission removals less than or equal to: • 10,000 tCO_2 eq per year, where maximum project area is 500 hectares (ha), for micro-scale activity • 16,000 tCO_2 eq per year for small-scale activity • No emission per year cap for large-scale activity
Mitigation type	☐ Emission reduction ☒ Emission removal
Project activity start date	The start date is the date of first planting activity.
Crediting period start date	The crediting period start date is the date of start of planting activity or a maximum of three years prior to the date of activity design certification, whichever occurs later.
Crediting period length	The crediting period shall be a minimum of 30 years and a maximum of 50 years. The project developer shall select the crediting period based on the characteristics of the activity. If any legal mandate comes into force during the crediting period, the activity can be credited only until the date the legal requirements take effect. Refer to methodology text; other limitations for crediting period may apply.

2| DEFINITIONS

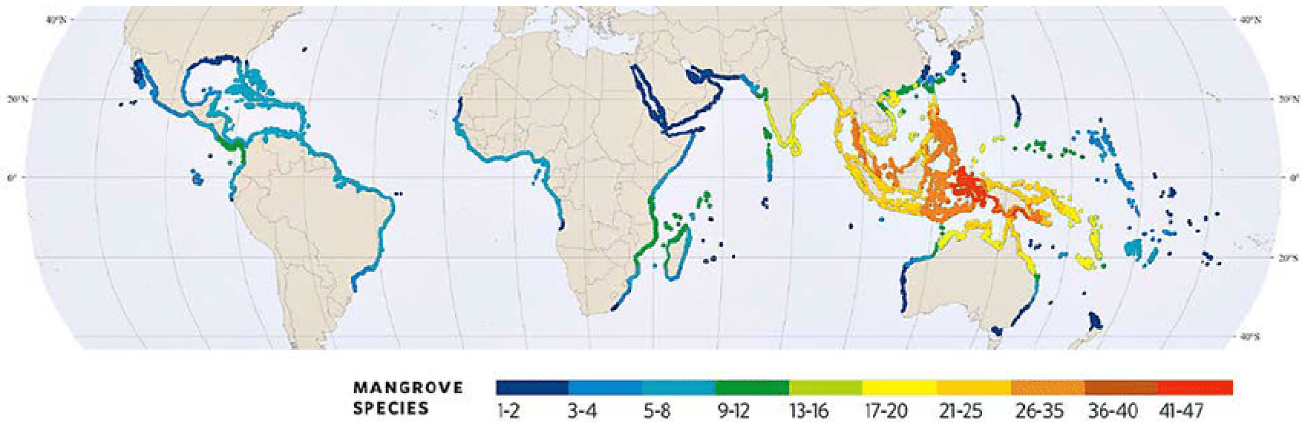
2.1.1 | In addition to the terms and definition listed in the GS4GG Glossary, the following definitions apply for this methodology.

Table 2. Terms and definitions

Term	Definition
Forest	Defined by the Designated National Authority (DNA) of the project's host country: http://cdm.unfccc.int/DNA/index.html. In case no forest definition is yet given by the DNA, the project activity developer can refer to both the national forest definition of the project's host country and the forest definition provided by the Food and Agriculture Organization of the United Nations: FAO Terminology Portal
Historic mangrove area	The area within the project area that was historically covered with natural mangrove forest according to the historic mangrove coverage since at least 10 years prior to the project start date. It is therefore the largest unit of possible project implementation but can consist of both eligible and non-eligible areas.
Historic mangrove coverage	An area where the occurrence of natural mangroves can be proven at least 10 years before the project start date. It is not limited to the project area but serves as an exclusion area whereby any mangrove mapped at any point later in time shall not be considered mangrove habitat within the project area.
Mangrove	Refer to Activity Requirements: Blue Carbon and Freshwater Wetlands. In addition, for this methodology, mangroves are defined as an association of halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters of tropical and sub-tropical coastlines. They are typically found between about 25°N and 25°S (see Figure 1).[1] Mangroves are classified into four major associations of differing structures, corresponding to physical, climatic, and hydrologic features of the environment in which they exist: (1) fringe or coastal mangrove, (2) riverine or estuarine mangrove, (3) basin mangrove, and (4) dwarf or scrub (or chaparro) mangroves.
Mangrove associate species	Flora representing non-arborescent, herbaceous, sub-woody, and climber species that grow mostly in regions adjoining the tidal periphery of mangrove habitats; also called "semi-mangroves."

[1] J. B. Kauffman and D. C. Donato, "Protocols for the measurement, monitoring, and reporting of structure, biomass, and carbon stocks in mangrove forests," Center for International Forestry Research (CIFOR), 2012. https://doi.org/10.17528/cifor/003749.

	Species that are naturally found growing and thriving together with mangrove species and do not necessarily fall under the definition of mangrove species.[2]
Mangrove deforestation	Reduction of mangrove canopy cover below the threshold of forest definition.
Mangrove species	A tree, shrub, palm, or ground fern generally exceeding 0.5 metres in height that normally grows above mean sea level in the intertidal zone of marine coastal environments and estuarine margins.[3] Mangrove species possess all or most of the following features: (1) occur only in mangrove environment and do not extend into terrestrial communities, (2) morphological specialisation (aerial roots, vivipary), (3) physiological mechanism for salt exclusion and/or salt excretion, (4) taxonomic isolation from terrestrial relatives.[4]
Modelling units (MU)	Distinct parts of the planting area where carbon stocks can be quantified based on a forest growth model. To meet the precision level for the carbon stocks estimation, MU areas normally have homogeneous characteristics in their growth patterns, silvicultural treatment, and planting date. The MU under the project scenario will exist once the project is implemented and operational.
Reference area	The area covered with mangrove species at the reference date. The mangrove cover at project date is compared to this reference area to map increase or decrease of mangrove cover.
Reference date	In this methodology, defined as 10 years prior to the project start date. At this point, the mangrove area is determined to serve as a reference in the land cover change analysis.



[2] P. B. Tomlinson, The Botany of Mangroves, 2nd ed. Cambridge: Cambridge University Press, 2016. https://doi.org/10.1017/CBO9781139946575.

[3] Ibid.

[4] Ibid.

Figure 1. World map of the mangrove distribution zones and the number of mangrove species along each region[5]

3| SCOPE, APPLICABILITY, AND ENTRY INTO FORCE

3.1 | Scope

3.1.1 | The methodology is applicable to an eligible activity that involves the reforestation of mangroves.

3.1.2 | Stakeholders are encouraged to submit requests for revisions to include other eligible ecosystems and/or proposed activities to expand the applicability scope. For details, refer to the Procedure for Development, Revision, and Clarification of Methodologies and Methodological Tools.

3.2 | Applicability

3.2.1 | The activities shall involve reforestation of native mangrove trees. Reforestation of mangrove-associate tree species that have been identified as historically related to native mangroves in the project area (based on peer-review information, global datasets,[6] or participatory historical land use analysis) may also be included alongside mangrove plantations.

3.2.2 | The methodology doesn't have any geographic limitations, i.e., it is globally applicable.

3.2.3 | This methodology shall be applied in conjunction with the latest version of Activity Requirements: Blue Carbon and Freshwater Wetlands and the GS4GG standards requirements and tool, as applicable.

3.3 | Entry into Force

3.3.1 | This methodology comes into force on its publication date.

4| NORMATIVE REFERENCES

4.1.1 | This methodology refers to the latest approved versions of the following documents:

[5] Deltares, "Habitat requirements for mangroves," 2014. [Online]. Quoted from:

N. N. Md Isa and M. N. Suratman, "Structure and Diversity of Plants in Mangrove Ecosystems," in *Mangroves: Ecology, Biodiversity and Management*, Springer International Publishing, 2021. Accessed: May 25, 2022. [Online]. Available: https://link.springer.com/chapter/10.1007/978-981-16-2494-0_15

[6] M. Spalding and M. Leal, "The State of the World's Mangroves 2021." Global Mangrove Alliance, 2021.

a. Activity Requirements: Blue Carbon and Freshwater Wetlands, Version 1.0
b. Afforestation/Reforestation GHG Emissions Reduction & Sequestration Methodology (hereafter referred to as "A/R Methodology"), version 2.1
c. Soil Organic Carbon Framework Methodology, version 1.0
d. Combined tool to identify the baseline scenario and demonstrate additionality in A/R clean development mechanism (CDM) project activities, version 01 (hereafter referred to as CDM AR-Tool02)
e. Estimation of non-CO2 GHG emissions resulting from burning of biomass attributable to an A/R CDM project activity, version 04.0.0 (hereafter referred to as CDM AR-Tool08)
f. Estimation of the increase in GHG emissions attributable to displacement of pre-project agricultural activities in A/R CDM project activity, version 02.0 (hereafter referred to as CDM AR-Tool15)

5| BASELINE AND PROJECT SCENARIO METHODOLOGY

5.1 | Project Boundary

5.1.1 | The methodology defines the following five spatial features (see Figure 2).The *historic mangrove coverage* refers to an area where the occurrence of natural mangroves can be proven for at least 10 years before the project start.

5.1.2 | The *historic mangrove area* refers to the overall area within the project area that was historically covered with mangrove forest according to the historic mangrove coverage. It is therefore the largest unit of possible implementation of the project but can encompass both eligible and non-eligible areas. Refer to section 5.5 for further details.

a. The *project area* refers to the area under the control of the project developers and encompasses the eligible and non-eligible areas for which GS4GG certification is requested. The project area could be composed of one single polygon or several non-contiguous polygons.

5.1.3 | The *eligible areas* are sections of the project area that are in compliance with eligibility criteria of this methodology. A detailed explanation of all the possible scenarios for delimiting eligible areas is presented in Section A1.1.65 (Step 4: Land cover change analysis and land eligibility assessment).

b. *Non-eligible areas* are sections of the project area that are not in compliance with the eligibility criteria of this methodology.

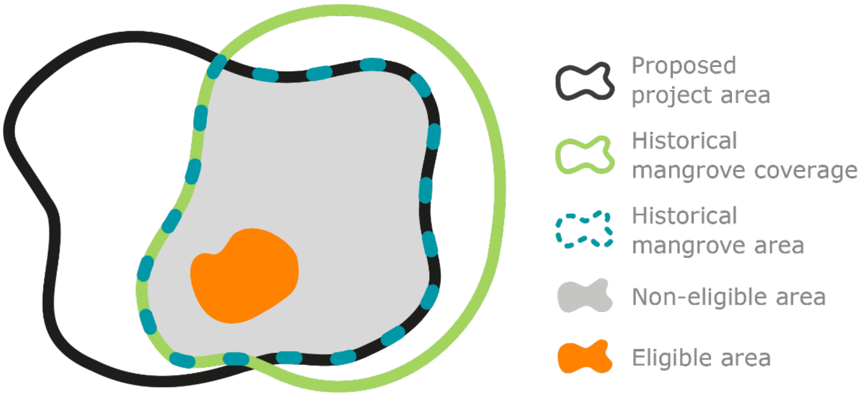


Figure 2. Schematic diagram of the different spatial categories used in this methodology guideline

5.1.4 | The spatial boundaries of the project areas shall be clearly defined to facilitate accurate and robust measuring, monitoring, and verifying of the emission reductions and removals.

5.1.5 | Projects shall define the boundaries for each spatial feature and explain the criteria and approach followed to define each boundary.

a. Vector information shall be provided for all geographical boundaries to unambiguously allow their identification.
b. The following information shall be provided for each identified project area in the project design document (PDD):
   i. Specific name and/or ID of the project area, and
   ii. Specific name and/or ID and the land cover type of each MU, and
   iii. Digital spatial data of the project boundaries and eligible project areas (using appropriate geographic information systems software formats[7]), and
   iv. Total land area in hectares for each spatial element, calculated using a planimetric formula, and
   v. Information about the legal rights of the landowner.

5.2 | Carbon Pools and Emission Sources Included in the Project Boundary

5.2.1 | The following carbon pools are considered eligible for this methodology.

Table 3. List of eligible carbon pools

Carbon pools		CO_2 removal	Baseline	Leakage
Tree biomass	Aboveground	Yes	Yes	Yes
	Belowground	Yes	Yes	Yes

[7] All vector files produced shall be Shapefile or geopackage; all raster files shall be TIFF.

Carbon pools		CO_2 removal	Baseline	Leakage
Non-tree biomass	Aboveground	Optional	Yes	No
	Belowground	Optional	Yes	No
Soil		Yes	Yes	Yes
Harvested wood (timber and energy wood)		No	No	No
Litter and lying deadwood		No	No	No

5.2.2 | Emission sources included in the project boundary are summarised in the table below.

Table 4. Emission sources included in or excluded from the project boundary

Source	Gas	Included	Justification
Emissions from wetland mineral soils (baseline and CO_2 removal)	CO_2	Yes	Considered under carbon pools
	CH_4	Optional	Published research[8] indicates that global CH_4 has the potential to offset the mangrove carbon burial values; however, there are also high uncertainties in the published value. Hence, more research of detailed global assessments is needed to fully demonstrate the accounting of this greenhouse gas (GHG). Until then, all CH_4 emissions from mangrove plantations are to be accounted for if found significant (more than 5% of project removals). It shall be established by the projects that CH_4 emissions are insignificant, either through scientific literature or field measurements, with the mangrove species and the ecological condition of the region being considered.
	N_2O	No	Considered negligible since N_2O global inputs slightly exceed total outputs, suggesting a net N balance in mangrove ecosystems.[9]
Other emissions (site preparation)	CH_4 and N_2O	Yes	Where existing tree and non-tree biomass of the baseline is burned for the purpose of land preparation, an additional 10% of the baseline shall be added in the first year of the activity. This is to

[8] J. A. Rosentreter, D. T. Maher, D. V. Erler, R. H. Murray, and B. D. Eyre, "Methane emissions partially offset 'blue carbon' burial in mangroves," *Sci. Adv.*, vol. 4, no. 6, p. eaao4985, June 2018, https://www.science.org/doi/10.1126/sciadv.aao4985.

[9] D. M. Alongi, "Nitrogen Cycling and Mass Balance in the World's Mangrove Forests," *Nitrogen*, vol. 1, no. 2, Art. no. 2, Dec. 2020, https://doi.org/10.3390/nitrogen1020014.

Source	Gas	Included	Justification
			account for N_2O and CH_4 emissions that are released during the burning process.
Other emissions	CO_2	Yes	CO_2 emissions from the combustion of fossil fuel for the management of mangrove plantations is to be quantified (e.g., dredging for tidal canals).
Combustion of fossil fuels	CH_4 and N_2O	No	Non-CO_2 GHG emissions from the use of fossil fuels from project activities (e.g., flights, management operations) are insignificant and may therefore be neglected.

5.3 | Demonstration of Additionality

5.3.1 | The regulatory surplus shall be demonstrated for all the activities, regardless of scale. The project shall demonstrate that proposed activity is neither directly mandated by law nor otherwise triggered by legal requirements (e.g., legally binding agreements, covenants, consent decrees, or contracts with government agencies or private parties). If such legal requirements are identified, crediting for the activity shall be allowed only until the date the legal requirements and their enforcement would take effect.

5.3.2 | The project developer shall demonstrate that the project could not or would not take place without carbon finance and shall demonstrate financial additionality by conforming to additionality requirements of one of the options below:

a. Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities (Version01) (unfccc.int) CDM AR-Tool02, or

b. Applicable A6.4 Standard for Additionality Demonstration as soon as it is available, or

c. Provisions described in Activity Requirements: Blue Carbon and Freshwater Wetlands.

5.4 | Baseline Scenario Determination

5.4.1 | The baseline scenario refers to the conditions that most likely would have occurred in the absence of the project. For baseline scenario identification, the project developer shall consider:

a. historical land management and practices occurring over the 10 years prior to the project start date when determining the baseline scenario, and

b. the existing national and local policies, stakeholder participation, and historical context (land uses, practices, and economic trends).

5.4.2 | The project developer shall determine the baseline scenario following the steps and sub-steps described in the latest version of CDM AR-Tool02 or applicable A6.4 tool as it becomes available. The steps below provide a summary of the requirements and illustrate the key considerations.

Step 1: Identification of alternative scenarios to the proposed project activities

5.4.3 | Project developer shall identify realistic and credible alternative scenarios that would have occurred within the project boundary in the absence of the project activities. The identified alternative scenarios shall include at least the following:

a. Continuation of the pre-project land use, and
b. Reforestation of the project areas without being registered as a carbon activity under any standard.

5.4.4 | For identifying the realistic and credible land use scenarios, field-based data, land use records, feedback from stakeholders, and participatory stakeholder assessments may be used as appropriate.

Outcome of Step 1: List of credible alternative scenarios that would have occurred in the project area.

Step 2: Barrier analysis

5.4.5 | Project developer shall identify a list of realistic and credible barriers that would prevent the implementation of at least one alternative scenario. Barriers can include institutional, technological, local ecological, and social conditions, and property rights, to name a few. Refer to Combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities for additional list of acceptable barriers. If there is only one alternative scenario that is not prevented by any barrier, this alternative scenario is identified as the baseline scenario.

Outcome of Step 2: List of alternative scenarios that are not prevented by the identified barriers.

Step 3: Investment analysis

5.4.6 | This step determines which of the remaining land use scenarios identified in Step 2 and its sub-steps is the most economically or financially attractive. For this purpose, an investment comparison analysis is conducted.

Outcome of Step 3: The alternative scenario that has the most attractive investment outcome.

Step 4: Common practice analysis

5.4.7 | The previous steps shall be complemented with an analysis of the extent to which mangrove reforestation activity has already diffused in the geographical area of the proposed activity. Diffusion beyond 20% of the total historical mangrove area of the host country would be treated as common practice. If information on area is not available, diffusion beyond 20% of the total number of projects may be considered. Areas under naturally occuring mangroves, activities registered with Gold Standard or any other carbon market program, and the activities supported by international climate finance shall be excluded from the analysis. This test is a credibility check to demonstrate additionality which complements the barrier analysis (Step 2) and, where applicable, the investment analysis (Step 3). The test shall establish that within the host country boundary, it is not a common practice to raise mangroves without revenue/income generated based on carbon credits or carbon finance. Refer to combined tool to identify the baseline scenario and demonstrate additionality in A/R CDM project activities for further details.

Outcome of Step 4: If Step 4 is satisfied, i.e., similar activities can be observed and essential distinctions between the proposed activity and similar activities cannot be made, the proposed activity is not additional. Otherwise, the proposed activity is not the baseline scenario and hence it is additional.

5.5 | Spatial Assessment for Delimiting Eligible Areas

5.5.1 | Appendix 1 of this methodology shall be referred to for conducting spatial assessment for delimiting eligible areas. The following paragraphs outline a summary of a step-wise approach and the minimum requirements for spatial data collection and analysis to identify current land cover and to analyse changes during the baseline scenario period (i.e., 10 years between the project start date and the earlier reference date) within the project area to determine eligible and non-eligible areas. Refer to Appendix 1 for further details about methodological workflow to be followed to delimit and define the eligible area.

Step 1: Delimitation of historic mangrove area

5.5.2 | Thematic layers or classified remote sensing imagery and topographic information from at least 10 years before the project start date shall be used to delimit the historic mangrove area within the proposed project area.

Step 2: Two land cover classifications of the project area

5.5.3 | The project developer shall use remote sensing data and tools to produce land cover maps for two points in time to be used in the change analysis in Step 4. The two timeframes are (1) at the project start date and (2) the reference date, i.e., 10 years prior to the project start date. The land cover classes shall include, at minimum, (1) mangrove and (2) no mangrove.

Step 3: Validation

5.5.4 | The land cover maps produced by remote sensing techniques shall be validated, and the accuracy shall meet the requirement listed in Appendix 1.

Step 4: Change analysis and eligibility assessment

5.5.5 | In order to define and quantify the eligible and non-eligible areas, the project developer shall analyse the land cover changes of mangrove deforestation in the baseline scenario period using the two land cover map outputs of Step 2.

Step 5: Identification of drivers of mangrove deforestation

5.5.6 | The project developer shall determine the drivers of mangrove deforestation to establish the underlying causes and find suitable remedies to protect the mangrove plantation within the activity.

5.6 | Quantification Approaches for Baseline and Project Scenarios

5.6.1 | Calculation of the emission removals (CO_2 removal units) is determined for every year (t) of the crediting period using the following formula:

$$ER_{s,t} = \left(CO2_{removal\ MU,t} - Baeline_{MU,t} - Leakage_{MU,t} - Other\ emissions_{MU,t}\right) \times Eligible\ planting\ area_{MU} \quad \text{Eq. 1}$$

$$CO2_{removal,project\ area,t} = \sum_{MU=1}^{MUs} \sum_{t=1}^{CP} CO2_{removal,MU,t} \quad \text{Eq. 2}$$

Where:

$CO2_{removal,project\ area,t}$	=	CO_2-removal units of a project area in year t (tCO_2)
$CO2_{removal,MU,t}$	=	CO_2-removal of a MU in year t (tCO_2)
MUs	=	MUs of a project area (1, 2, 3, …)
t	=	Years of the crediting period (1, 2, 3, …)
CP	=	Year the crediting period ends (1, 2, 3, …)

5.6.2 | The CO_2 removal units are calculated cumulatively based on the growth of the mangrove forest. This means that during the start of the project, emissions from other parameters, such as the baseline emissions, other emissions, and leakage emissions, are considerably higher than the CO_2 removal, therefore having a negative net CO_2 sequestration. In this case, no CO_2 removal units are generated. Only when the accumulation becomes positive can CO_2 removal units be issued. The following sections specify the different equations comprising the calculation of the CO_2 removal units.

a. <u>Aboveground biomass and carbon stocks</u>

5.6.3 | This methodology offers four quantification approaches to estimate aboveground biomass for baseline and project scenarios as summarised in the following table.

Table 5. Aboveground biomass and carbon stock measurement approach

Scenario	Ex-ante estimation	Ex-post estimation
Baseline scenario	Approach 3 or 4	Approach 1 with Approach 2, or Approach 2
Project scenario	Approach 3 or 4	Approach 1 with Approach 2, or Approach 2

5.6.4 | Specifically, approaches 3 and 4 only allow for ex-ante estimation. For the ex-post estimation, the methodology allows the use of Approach 1 with Approach 2 or only Approach 2.

Approach 1. Remote sensing

5.6.5 | Estimation of aboveground biomass via remote sensing assessment requires developing a correlation between spectral signatures and on-the-ground biomass measurements.

5.6.6 | With this approach, remote sensing outputs shall be validated against the results of sample-based, project-specific forest inventories (Approach 2).

5.6.7 | The methodology allows for the application of any remote sensing products and algorithms. The accuracy of remote sensing products shall be assessed and reported in the PDD.

5.6.8 | Remote sensing products and/or technologies can be used to quantify carbon pools and issue GSVERs only once Gold Standard rules and requirements that allow for issuance of GS-VERs based on remote sensing products and/or technologies are published. In the absence of such requirements, the methodology permits using remote sensing products only in association with Approach 2, and the proposed approach shall be assessed at the time of design review and in subsequent performance reviews.

5.6.9 | The methodology contemplates three scenarios as summarised below for the application of remote sensing products for the assessment of aboveground biomass. Of the three scenarios, the methodology offers only Scenario 1 (S1) for application; Scenario 2 (S2) and Scenario 3 (S3) may be made available for ex-post estimations in future versions of the methodology.

a. Scenario 1 (S1): Requires the use of on-site, project-specific biomass data from a forest field survey to calibrate and validate remote sensing outputs.

b. Scenario 2 (S2) (not eligible): Requires the use of either on-site, project-specific biomass data from a forest inventory or secondary, peer-reviewed datasets applicable to the project area to calibrate and validate remote sensing outputs.

c. Scenario 3 (S3) (not eligible): Direct application of remote sensing outputs to the project area based on calibration and validation results from the application of the same remote sensing technology in other comparable areas.

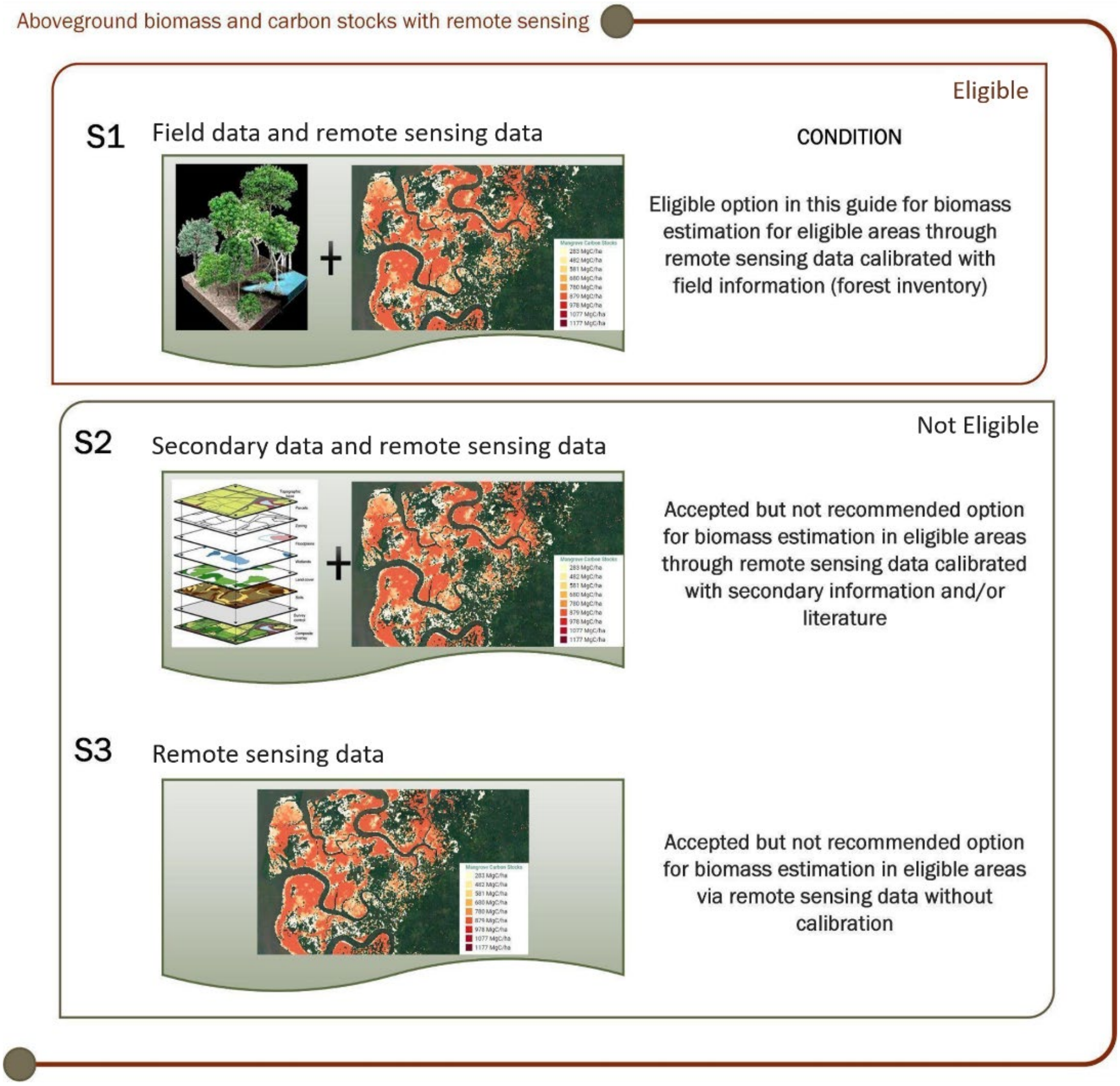


Figure 3. Aboveground biomass and carbon stocks with remote sensing

5.6.10 | S1, regression analysis between on-site biomass measurements and remote sensing biomass estimations, requires the application of a linear regression (linear in the parameters) to assess the relationship between remote sensing measurements of biomass ("estimated values") and the biomass estimations via a forest inventory ("observed values").

5.6.11 | The project developer shall include the details as an annex to the PDD, describing the approach followed for developing the regression analysis, including, but not limited to:

a. Type of regression (linear or nonlinear) and the regression equation used

b. Stratification criteria and process prior to selecting the number of sample points and allocating the samples by strata
c. The independent variables considered in the regression equation, indicating, explaining, and justifying the inclusion of each variable
d. A scatter plot including all data points
e. Assessment of the regression assumptions and how each is fulfilled, demonstrating that both the coefficients and the standard errors are reliable, including the following:
    i. Linearity
    ii. Constant error variance
    iii. Independent error terms
    iv. Normal errors
    v. No-multicollinearity
    vi. Exogeneity
f. Report of the number of sample points (n), R^2, adjusted-R^2, standard error of the regression, p-value for the regression, p-value of each coefficient, and confidence intervals at the 95% confidence level for each coefficient

5.6.12 | To supplement the regression analysis, the project developer shall provide supporting documentation in the form of a spreadsheet that shall contain:

a. all the data used for the regression analysis to allow replicability, and
b. a scatterplot with all sample points, and
c. all calculations demonstrating that all regression assumptions are fulfilled, and
d. the regression equation calculated for the estimation of biomass, and
e. regression output indicating at least the number of sample points (n), R^2, adjusted-R^2, and standard error of the regression.

5.6.13 | The selection of a non-linear regression is permitted only if:

a. the project can justify, based on relevant peer-reviewed literature, the adequacy of the non-linear regression between estimated and observed values of Aboveground Biomass (AGB) applicable to the selected sensor and conditions of the biomass in the project area.
b. An adequate goodness-of-fit measure is submitted and justified as applicable; note that R^2 and adjusted-R^2 are not adequate goodness-of-fit measures for non-linear regressions.

Approach 2: In situ measurements and site-specific models

5.6.14 | This approach requires conducting a forest inventory with in situ measurements to estimate tree biomass. The project developer shall follow the requirements for conducting a forest inventory as detailed in the A/R Methodology.

Approach 3: Local or regional datasets and/or models

5.6.15 | This approach is allowed only for baseline emissions estimation and allows issuance of Planned Emission Removals (GSPERs)—ex-ante carbon credits. Issuance of GSVERs is not permitted.

5.6.16 | Local or regional datasets and/or models from peer-reviewed publications shall be used to model the baseline and project emissions. Published research publications, such as Giri et al. (2011),[10] Hamilton and Casey (2016),[11] and Murray et. al. (2022),[12] can be applied. The aptness of the source applied shall be assessed at the time of design review by the validation and verification body (VVB).

Approach 4: IPCC default values

5.6.17 | This approach is allowed only for baseline emissions estimation and for ex-ante estimations. If Approach 4 is applied, issuance of GSPERs or GSVERs is not permitted.

5.6.18 | Based on IPCC default values to estimate carbon stock (2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Chapter 4, Table 4.3), this approach should only be applied when Approach 3 cannot be applied.

b. Belowground biomass and carbon stocks

5.6.19 | Belowground tree biomass shall be calculated from aboveground biomass using an appropriate root to shoot ratio.

$$Belowground\ biomass = Aboveground\ biomass \times Root\ to\ shoot\ ratio \qquad \text{Eq. 3}$$

Where:

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[10] C. Giri et al., "Status and distribution of mangrove forests of the world using earth observation satellite data," Glob. Ecol. Biogeogr., vol. 20, no. 1, pp. 154–159, 2011, doi: https://doi.org/10.1111/j.1466-8238.2010.00584.x.

[11] S. E. Hamilton and D. Casey, "Creation of a high spatio-temporal resolution global database of continuous mangrove forest cover for the 21st century (CGMFC-21)," Glob. Ecol. Biogeogr., vol. 25, no. 6, pp. 729–738, 2016, doi: https://doi.org/10.1111/geb.12449.

[12] Murray, N.J., Worthington, T.A., Bunting, P., Duce, S., Hagger, V., Lovelock, C.E., Lucas, R., Saunders, M.I., Sheaves, M., Spalding, M. and Waltham, N.J., 2022. High-resolution mapping of losses and gains of Earth's tidal wetlands. Science, 376(6594), pp.744-749

Belowground biomass	=	Aboveground biomass derived from applying approach 1 to 4
Root to shoot ratio	=	The root-to-shoot ratio shall be based on either one of the following: i. field-based measurements, or ii. scientific literature or internationally peer-reviewed journal publications and three default factors as prescribed by the IPCC[13] (0.49 for tropical wet areas, 0.29 for tropical dry areas, 0.96 for sub-tropical areas for tree biomass, and 4.0 for non-tree biomass).

c. Soil organic carbon

5.6.20 | For soil organic carbon (SOC) quantification, the project developer shall apply one of the approaches of the Soil Organic Carbon Framework Methodology[14] for the quantification of SOC, with the following guidelines:

a. Any of the three quantification approaches (i.e., direct measurement, peer-reviewed data/models, or national/regional default values) as outlined in the latest version of the Soil Organic Carbon Framework Methodology can be used to measure SOC in project area. Per the selected approach, the project developer shall apply the quantification approaches that demonstrate full compliance with underlying requirements.

b. No separate SOC activity module is required to apply the approaches of the Soil Organic Carbon Framework Methodology in the context of this methodology.

5.6.21 | The project shall apply the mangrove-specific soil sampling methods as outlined in Appendix 2 of this methodology.[15]

5.6.22 | In addition to the use of the Soil Organic Carbon Framework Methodology, project developers shall also determine the SOC from autochthonous (SOC

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[13] H. Kennedy *et al.*, "IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Chapter 4: Coastal Wetlands." Intergovernmental Panel on Climate Change, 2013.

[14] Gold Standard, "402_V1.0_LUF_AGR_FM_Soil-Organic-Carbon-Framework-Methodolgy.pdf." Gold Standard, 2020. Accessed: Jul. 23, 2021. [Online]

[15] The project developers/stakeholders are encouraged to submit any other sampling method or protocol not included in Appendix 2 by submitting a revision to the methodology following Procedure for the Development, Revision, and Clarification of Methodologies and Methodological Tools

originating in the project area from vegetation regrowth) and allochthonous (SOC originating outside the project area and being deposited in the project area) sources.

c. The project developers may follow any of the three quantification approaches of the Soil Organic Framework Methodology (i.e., direct measurement, peer-reviewed data/models, or national/regional default values) for quantification of the allochthonous and autochthonous SOC.

5.6.23 | The VVB shall validate compliance of the measurement approach applied with applicable requirements to the approach of the Soil Organic Carbon Framework Methodology.

5.7 | Baseline Emissions

5.7.1 | The use of Approaches 1-4 for aboveground biomass and carbon stock is allowed for the baseline emissions estimation. The baseline emissions shall be determined on an MU level as follows:

Eq. 4

$$\text{Baseline MU, t}\left(\frac{\text{tCO2}}{\text{ha}}\right) = \text{Baseline Eligible area, MU (tCO2)}\Big/\text{Eligible planting area (ha)}$$

Where:

Baseline MU, t	=	Baseline emissions (tCO_2/ha) for each MU
Baseline Eligible area, MU	=	Baseline emissions (tCO_2) found in the eligible project area
Eligible planting area	=	Area of eligible land for the project activities
t	=	Baseline is deducted in the first year (t=1)

5.7.2 | The results, including the uncertainty reduction using the uncertainty discounting approach based on latest GS4GG requirements, comprise the baseline $_{\text{Eligible area, MU}}$ (tCO_2). The equations for other emissions and leakage emissions are presented in the succeeding sections and are deducted in the first year.

$$\text{Baseline}_{\,Eligible\ area,MU,(tCO2)} = \left(\text{AGC}_{\text{Eligible area},MU} + \text{BGC}_{\text{Eligible area,MU}} + \text{SOC}_{\text{Eligible area,MU}}\right) - \left(\text{OE}_{\text{Eligible area},MU} + \text{LE}_{\text{Eligible area,MU}}\right) \quad \text{Eq. 5}$$

Where:

$\text{Baseline}_{\text{Eligible area,MU}}$	=	Baseline emissions (tCO_2) found in the eligible project area of MU *n*
$\text{AGC}_{\text{Eligible area,MU}}$	=	Aboveground carbon (tCO_2) found in the eligible project area of MU *n*
$\text{BGC}_{\text{Eligible area,MU}}$	=	Belowground carbon (tCO_2) found in the eligible project area of MU *n*
$\text{SOC}_{\text{Eligible area,MU}}$	=	SOC (tCO_2) found in the eligible project area of MU *n*
$\text{OE}_{\text{Eligible area,MU}}$	=	Other emissions (tCO_2) found in the eligible project area of MU *n*
$\text{LE}_{\text{Eligible area,MU}}$	=	Leakage emissions (tCO_2) found in the eligible project area of MU *n*
n	=	MU number

5.7.3 | The total baseline emissions are then calculated as the sum of all baseline emissions per MU in the eligible project areas:

$$Baseline\ emissions\left(\frac{tCO2}{ha}\right) = \sum_{MU=1}^{MUs}\left(Baseline_{MU,t}\right) \quad \text{Eq. 6}$$

Where:

Baseline Emissions (tCO_2/ha)	=	Total baseline emissions (tCO2/ha) from all MUs in the eligible project area
Baseline MU,t	=	Baseline emissions (tCO2/ha) for each MU
T	=	years

5.8 | Estimation of CO_2 Removal

5.8.1 | The CO_2 removal or project scenario emissions shall be determined on an MU level using the following process. Aboveground biomass estimates can be determined using the results from Section 5.6 of this methodology.

5.8.2 | The CO_2 removal is determined by the tree biomass when an MU reaches its equilibrium. In the event that the tree biomass is still increasing at the end of the crediting period, the CO_2 removal is determined by the tree biomass of an MU in the year the crediting period ends.

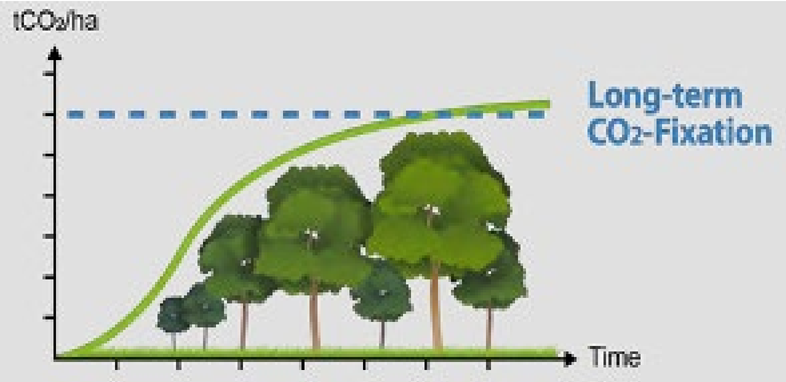

Figure 4.Long-term CO_2 fixation

5.8.3 | CO_2 removal is:

$$\text{CO2 removal MU, t}\left(\frac{\text{tCO2}}{\text{ha}}\right) = \text{CO2 removal Eligible area (tCO2)} \Big/ \text{Eligible planting area (ha)} \quad \text{Eq. 7}$$

Where:

CO_2 removal $_{MU,t}$	=	CO_2 removal (tCO_2/ha) for each MU
CO_2 removal $_{Eligible\ area}$	=	CO_2 removal (tCO_2) found in the eligible project area
Eligible planting area	=	Area of eligible land for the project activities
t	=	Year of activity implementation

5.8.4 | The total project removals are then calculated as the sum of all project emissions per MU in the eligible project area:

$$\text{CO2 project removal (tCO2)} = \sum_{t=1}^{T}(CO2\ removal\ MU, t) \quad \text{Eq. 8}$$

Where:

CO_2 project removal	=	Total CO_2 removal (tCO_2/ha) from all MUs in the eligible project area
CO_2 removal $_{MU,t}$	=	CO_2 removal (tCO_2/ha) for each MU

t	=	Year when crediting period ends

5.9 | Leakage Emissions

5.9.1 | Leakage is the GHG emissions which occur outside the project area and are quantified and can be attributed to the project activities. Four categories of leakage are to be considered:

1. Collection of wood (for firewood, charcoal, etc.)
2. Timber harvesting
3. Agriculture (crop cultivation, shrimp cultivation, etc.)
4. Livestock

5.9.2 | In the context of this methodology, one or more of the above leakage categories can occur[16 17 18]; hence, leakage shall be quantified on an MU level and deducted in the first year (t=1), as follows:

$$\text{Leakage MU, t}\left(\frac{\text{tCO2}}{\text{ha}}\right) = \text{Leakage Project area (tCO2)} \big/ \text{Eligible planting area (ha)} \quad \text{Eq. 9}$$

Where:

Leakage $MU_{,t}$	=	Leakage (tCO_2/ha) for each MU
Leakage $_{\text{Project area}}$	=	Leakage (tCO_2/ha) found in the project area
Eligible planting area	=	Area of eligible land for the project activities

5.9.3 | In terms of quantifying the four categories of leakage, the following equations shall be used. For leakage categories 1, 2, and 3 mentioned in Section 5.9.1:

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[16] Rosentreter, J.A.; Maher, D.T.; Erler, D.V.; Murray, R.H.; Eyre, B.D. Methane Emissions Partially Offset "Blue Carbon" Burial in Mangroves. *Sci. Adv.* 2018, *4*, eaao4985, doi:10.1126/sciadv.aao4985.

[17] Kauffman, J.B.; Bhomia, R.K. Ecosystem Carbon Stocks of Mangroves across Broad Environmental Gradients in West-Central Africa: Global and Regional Comparisons. *PLOS ONE* 2017, *12*, e0187749, doi:10.1371/journal.pone.0187749.

[18] Sasmito, S.D.; Sillanpää, M.; Hayes, M.A.; Bachri, S.; Saragi-Sasmito, M.F.; Sidik, F.; Hanggara, B.B.; Mofu, W.Y.; Rumbiak, V.I.; Hendri; et al. Mangrove Blue Carbon Stocks and Dynamics Are Controlled by Hydrogeomorphic Settings and Land Use Change. *Glob. Change Biol.* 2020, *26*, 3028–3039, doi:https://doi.org/10.1111/gcb.15056.

$$\text{Leakage project area (tCO2)} = \text{Area (ha)} \times \text{\% of activity shift (\%)} \times \text{CO2 stock (tCO2/ha)} \quad \text{Eq. 10}$$

Where:

Area	=	Land within the project area where the activity is taking place
% of activity shift	=	Percentage of the activity that will be displaced during the crediting period and will impact the tree biomass outside the project area
CO_2 stock	=	Average stock of tree biomass in the area to where the activity will be displaced

Note: If it is not known to where the activity will be displaced, the CO_2 stock = the average stock of tree biomass of a natural forest in the project's host country.

5.9.4 | While category 4 (livestock) is not often observed in mangrove areas, in the event that this is identified as a leakage activity, the following formula shall be used to account for the leakage value:

$$Leakage\ project\ area\ [tCO2] = Displaced\ heads\ [head] \times\ Grazing\ capacity\ \left[\frac{ha}{head}\right] \times\ CO2\ stock\ [tCO2/ha] \quad \text{Eq.11}$$

Where:

Displaced heads	=	Amount of heads that: a. will be displaced during the crediting period, and b. will have impact on the tree biomass outside the project area. The factor is determined by: a. credible estimations, or b. a representative survey.
Grazing capacity	=	Grazing capacity of the area to where the livestock will be displaced
CO_2-stock	=	Average stock of tree biomass in the area to where the activity will be displaced If it is not known to where the activity will be displaced, the CO_2 stock = the average stock of tree biomass of a natural forest in the project’s host country.

5.10 | Other Emissions

5.10.1 | The emissions from certain land or site preparation activities shall be accounted for as project emissions.

5.10.2 | Site preparation: Where existing tree and non-tree biomass of the baseline is burned for the purpose of land preparation or where additional mangrove-related site preparation is conducted (e.g., ensuring tidal flow of the planting areas), an additional 10% of the baseline emissions shall be deducted. This is to account for the non-CO_2 GHG emissions (N_2O and CH_4) that are released during the burning process.

5.10.3 | Combustion of fossil fuels: Non-CO_2 GHG emissions from the use of fossil fuels from project activities (e.g., flights, management operations) are insignificant and may therefore be neglected.

5.10.4 | CO_2 emissions from activities related to management of mangroves are to be accounted for. This may include, for instance, fossil fuel used for dredging of tidal canals or operating some equipment for management of mangrove planting. To account for the emissions, the latest GS4GG requirements on project emissions from fossil fuel consumption shall be referred to.

5.10.5 | Mangrove plantations can emit methane. It has to be estimated whether there is a significant amount of methane emissions (more than 5% of project removals) owing to the mangrove plantations. Methane emissions are to be accounted for if significant. To demonstrate the amount of methane emissions, scientific literature that is relevant to the region and the species being planted may be considered.

5.11 | Data and Parameters Not Monitored

Parameter ID	SMM-1
Data/Parameter:	$NT_{biomass}$
Data unit:	Tons of CO_2 per hectare
Description:	Non-tree biomass during the crediting period
Source of data:	Project developer
Measurement procedure if any:	-
Any comment:	-

Parameter ID	SMM-2
Data/Parameter:	44/12

Data unit:	tCO_2/tC
Description:	Factor used to convert C into CO_2
Source of data:	-
Measurement procedure if any:	-
Any comment:	-

Parameter ID	SMM-3
Data/Parameter:	Root-to-shoot ratio
Data unit:	Dimensionless
Description:	Used to calculate belowground biomass
Source of data:	Root-to-shoot ratio shall be based on one of the following: 1) field-based information, or 2) scientific literature or internationally peer-reviewed journal publications, or 3) default factors as prescribed by the IPCC[19] (0.49 for tropical wet areas, 0.29 for tropical dry areas, 0.96 for sub-tropical areas for tree biomass, and 4.0 for non-tree biomass).
Measurement procedure if any:	-
Any comment:	-

Parameter ID	SMM-4
Data/Parameter:	Carbon fraction
Data unit:	tC/tdm
Description:	The share of carbon dry tree biomass; default for all mangrove species is 0.47
Source of data:	What Is the True Carbon Fraction Value of Mangrove Biomass? Rahman et al. (2023). Malaysian Journal of Science 42(2): 67-72
Measurement procedure if any:	-

[19] H. Kennedy et al., "IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Chapter 4: Coastal Wetlands." Intergovernmental Panel on Climate Change, 2013.

Any comment:	-

6| UNCERTAINTY QUANTIFICATION

6.1.1 | The project proponent shall use a precision of 20% of the mean at the 90% confidence level as the criteria for accuracy of total project removals. This target precision shall be achieved by selecting appropriate models, parameters, sampling, and measurement techniques in accordance with the latest requirements on uncertainty assessment under GS4GG.

6.1.2 | The results, including the uncertainty reduction using the uncertainty discounting approach of the Land Use & Forests (LUF) Activity Requirements (or any other latest guidance under GS4GG on uncertainty), comprise the CO_2 removal $_{\text{Eligible area}}$ (tCO_2).

$$\begin{aligned} \text{CO2 removal Eligible area, MU (tCO2)} &= (\text{AGC Eligible area, MU} + \text{BGC Eligible area, MU} \\ &+ \text{SOC Eligible area, MU}) \\ &- (\text{OE Eligible area, MU} + \text{LE Eligible area, MU}) \end{aligned} \quad \text{Eq. 12}$$

Where:

CO_2 removal $_{\text{Eligible area,MU}}$	=	CO2 removal (tCO2) found in the eligible project area of MU n
$AGC_{\text{Eligible area,MU}}$	=	Aboveground carbon (tCO2) found in the eligible project area of MU n
$BGC_{\text{Eligible area,MU}}$	=	Belowground carbon (tCO2) found in the eligible project area of MU n
$SOC_{\text{Eligible area,MU}}$	=	SOC (tCO2) found in the eligible project area of MU n
$OE_{\text{Eligible area,MU}}$	=	Other emissions (tCO2) found in the eligible project area of MU n
$LE_{\text{Eligible area,MU}}$	=	Leakage emissions (tCO2) found in the eligible project area of MU n
n	=	MU number

7| CHANGES REQUIRED FOR CREDITING PERIOD RENEWALS

7.1 | Crediting Period Renewal Requirements

7.1.1 | The latest version of the methodology shall be applied at the time of crediting period renewal.

7.1.2 | The regulatory surplus shall be assessed by the activity at each crediting period.

7.1.3 | A change in approach from the first crediting period to the succeeding crediting period shall meet the following conditions and procedures:

a. If Approach 1 or 2 is used for the quantification of AGB in the first crediting period, a change to either Approach 3 or 4 for subsequent crediting period is not allowed.

b. Quantifications from both approaches shall be compared, and differences shall be reviewed with conditions below:

   i. Neutral change: If the calculated stocks from Approach 1 or 2 do not differ by more than 5% of the calculated and verified stocks from the first crediting period (Approach 3 or 4), the change can be considered as neutral and may be allowed. The result of Approach 1 or 2 shall be used for the calculations.

   ii. Biomass change (measured): If the calculated stocks from Approach 2 differ by more than 5% of the calculated and verified stocks from the first crediting period (Approach 3 or 4), the validity of the data parameters used shall be reviewed at project validation. The VVB will decide if the model and data are acceptable, and the value from the first crediting period shall be corrected accordingly.

   iii. Biomass change (measured and modelled): If the calculated stocks from Approach 1 differ by more than 5% of the calculated and verified stocks from the crediting period (Approach 2), the validity of the data parameters used shall be reviewed at project validation. The VVB will decide if the model and data are acceptable, and the value from the first verification shall be corrected accordingly.

7.1.4 | Below is a summary of the approach change from the crediting period to the succeeding crediting period and corresponding outcomes.

Table 6. Summary of approach change from first to succeeding verifications

First crediting period	Succeeding crediting period	Condition
Approach 1	Approach 2	Allowed
Approach 2	Approach 1	Allowed

Approach 3 or 4	Approach 1 or 2	Allowed
Approach 1 or 2	Approach 3 or 4	Not allowed

8| MONITORING METHODOLOGY

8.1 | Data and Parameters Monitored

8.1.1 | The projects shall follow the latest version of the Monitoring Report Template Guide to ensure that the information complies with the Gold Standard documents and is applicable to the project framework type, in particular to the Principles and Requirements as well as the Activity Requirements: Blue Carbon and Freshwater Wetlands. Remote sensing–related parameters shall follow the guidelines from the GS4GG Monitoring, Reporting, and Verification Methodology.

Parameter ID	SMM-5
Data/Parameter:	Emission reductions in tCO_2-equivalents: baseline
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	The baseline scenario is defined as the reasonable, conservative scenario that would exist in the absence of the project. While setting the baseline scenario, the project developer shall take into account the relevant applicable legislation and how effectively these are enforced as defined in the GS4GG Glossary.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity according to the Activity Requirements: Blue Carbon and Freshwater Wetlands.
Monitoring frequency:	At least once during a five-year certification cycle

QA/QC procedures:	These procedures will be established before design certification. However, it is suggested to: a. establish a feasible QA/QC plan to ensure data quality, and b. implement the QA/QC plan, and c. document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[20]
Any comment:	-

Parameter ID	SMM-6
Data/Parameter:	Emission reductions in tCO_2 equivalents: wood density
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	The wood density is the ratio between the mass of dry wood divided by its volume as defined in the GS A/R Methodology.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity. Data obtained from direct measurements ex situ or in situ or from proxy methods shall follow the Activity Requirements: Blue Carbon and Freshwater Wetlands and the Soil Organic Carbon Framework Methodology.
Monitoring frequency:	At least once during a five-year certification cycle

[20] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: a. establish a feasible QA/QC plan to ensure data quality, and b. implement the QA/QC plan, and c. document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[21]
Any comment:	-

Parameter ID	SMM-7
Data/Parameter:	Emission reductions in tCO_2 equivalents: soil carbon
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	The carbon component of soil organic matter. The amount of soil organic matter depends on soil texture, drainage, climate, vegetation, and historical and current land use.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity according to the Activity Requirements: Blue Carbon and Freshwater Wetlands.
Monitoring frequency:	At least once during a five-year certification cycle. Also shall submit an Annual Report Template based on the methodology´s applicability conditions as described in Section 16 of the Soil Organic Carbon Framework Methodology.

[21] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: a. establish a feasible QA/QC plan to ensure data quality, and b. implement the QA/QC plan, and c. document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[22]
Any comment:	

Parameter ID	SMM-8
Data/Parameter:	Emission reductions in tCO_2-equivalents: other emissions
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	The emissions from certain land or site preparation activities shall be accounted for the CO_2 removal or project scenario adopted from Section 3.8 of the GS A/R Methodology, version 2.1 or a future version thereof.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity according to the Activity Requirements: Blue Carbon and Freshwater Wetlands.
Monitoring frequency:	At least once during a five-year certification cycle

[22] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: • establish a feasible QA/QC plan to ensure data quality, and • implement the QA/QC plan, and • document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[23]
Any comment:	

Parameter ID	SMM-9
Data/Parameter:	Emission reductions in tCO_2 equivalents: leakage
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	Leakage is emissions that occur due to a shift of activities from the inside of a project area to the outside of a project area.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity according to the Activity Requirements: Blue Carbon and Freshwater Wetlands.
Monitoring frequency:	At least once during a five-year certification cycle
QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: • establish a feasible QA/QC plan to ensure data quality, and • implement the QA/QC plan, and • document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[24]

[23] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

[24] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

Any comment:	-

Parameter ID	SMM-10
Data/Parameter:	Project emissions
Data unit:	Tonnes of CO_2 equivalents/hectare
Description:	Project emissions are the GHG emissions caused by the project. They have to be deducted from the project's emission reductions. The main source is site preparation. Where existing tree and non-tree biomass of the baseline is burned for the purpose of land preparation, an additional 10% of the baseline shall be deducted. This is to account for N_2O and CH_4 emissions that are released during the burning process. Based on project-specific data, a lower percentage may be applied when justified based on relevant literature and other sources.
Source of data:	The values shall be selected and considered as the most appropriate for the different MUs that compose the activity according to the Activity Requirements: Blue Carbon and Freshwater Wetlands.
Monitoring frequency:	At least once during a five-year certification cycle
QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: ● establish a feasible QA/QC plan to ensure data quality, and ● implement the QA/QC plan, and ● document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[25]
Any comment:	CO_2 and non-CO_2 GHG emissions caused by the use of fossil fuel from project activities (flights, management operations, etc.) are insignificant and may therefore be neglected.

[25] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

Parameter ID	SMM-11
Data/Parameter:	Aboveground tree volume
Data unit:	m^3/hectare
Description:	The aboveground tree volume is the basis for the calculation of aboveground and belowground tree biomass. Together, these values give tree biomass, which represents the main carbon pool in a mangrove forest.
Source of data:	• Approach 1: Remote sensing, or • Approach 2: In situ measurements and site-specific models, or • Approach 3: Local or regional datasets and/or models (only for *ex-ante* estimations), or • Approach 4: Based on IPCC default values (only for *ex-ante* estimations). In situ measurements shall follow the GS A/R Methodology, version 2.1.
Monitoring frequency:	At least once during a five-year certification cycle
QA/QC procedures:	These procedures shall be established before design certification. However, it is suggested to: • establish a feasible QA/QC plan to ensure data quality, and • implement the QA/QC plan, and • document and report the QA/QC activities. Additional guidance can be found in the IPCC´s document on QA/QC of Inventory Systems.[26]
Any comment:	If stem volume is obtained under Approach 1, it has to be multiplied with the biomass expansion factor (BEF). Note the following: • Some BEFs already include the root-to-shoot ratio.

[26] J. Mangino, "QA/QC of Inventory Systems." Intergovernmental Panel on Climate Change. [Online]. Available: https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/6_2_QA_QC.pdf

	• The stem volume is based on a specific diameter of stump (x cm). The BEF shall relate to this. • Most root-to-shoot ratios are calculated from the tree volume (including branches and leaves/needles), but some are based on the stem volume. • In cases where a biomass conversion and expansion factor is used, the factors BEF and wood density are both integrated. • The BEF can be age-dependent and thus change over time.

APPENDIX 1| Guidelines for Conducting Spatial Assessments to Define Eligible Areas

Appendix 1 outlines the best practice approach for conducting the spatial assessment to delimit the eligible areas for applying this methodology. This information provides a step-by-step guide on how to conduct the assessment for compliance with Section 5.5 of the methodology.

Figure A.1.1 provides a general framework for the eligibility analysis for mangrove deforestation and degradation, including the historical analysis and identification of drivers of mangrove degradation.

Step 1: Delimitation of historic mangrove area

Step 1.1: Delimiting historic mangrove coverage

A1.1.1 | The historic mangrove coverage represents the largest mangrove extent that once existed in the region at least 10 years before the project start date. The historical mangrove coverage can be provided by combination of the following sources, which were published at least 10 years before the project start date:

a. Global Mangrove Watch (GMW): An online platform for mapping and monitoring mangroves all over the world. The current release of the GMW dataset consists of seven annual extent maps based on optical and radar information and spanning from 1996 to 2020; all of these are available on the GMW platform. It is possible to add all possible layers of GMW. The maps were computed at a 25-metre ground resolution. This can be used as a coarse mechanism to delineate historical mangrove areas with one of the following options:

   i. Option 1: *A land cover classification map with a distinct class "mangrove"* conducted by the project developer in the project area with a level of accuracy as presented in Step 3: Validation, showing land cover at least 10 years prior to the project start date. Refer to Step 2.1: Data collection for the criteria (spatial resolution, quality, etc.) of the remote sensing data to be used for the land cover classification. Option 2, below, is to be considered only if Option 1 is not available.

   ii. Option 2: *National maps of vegetation, ecosystems, or land cover where mangrove coverage is one of the mapped land cover categories* from official sources at a map scale equal to or higher than 1:60,000 or with a minimum spatial resolution of 30 metres. When already interpreted data is available, it shall be used with some caution.[27] Option 2 also shall include either an expert opinion or appraisal from the community living next to the project area to ascertain the extent.

A1.1.2 | Cartographic and spatial documentation shall be accompanied by metadata according to ISO 19115-2014 (geographic information metadata) standards.

A1.1.3 | The historic mangrove area for the project area shall be extracted from the source above; the resulting vector file shall contain the initial historical mangrove area that will be intersected with the proposed project area.

[27] If maps do not report documentation, then error estimates, whether they were of the site or region in question, the minimum mapping unit, the methods used to produce these data, and descriptions of the classes and/or categories must be compiled, etc.

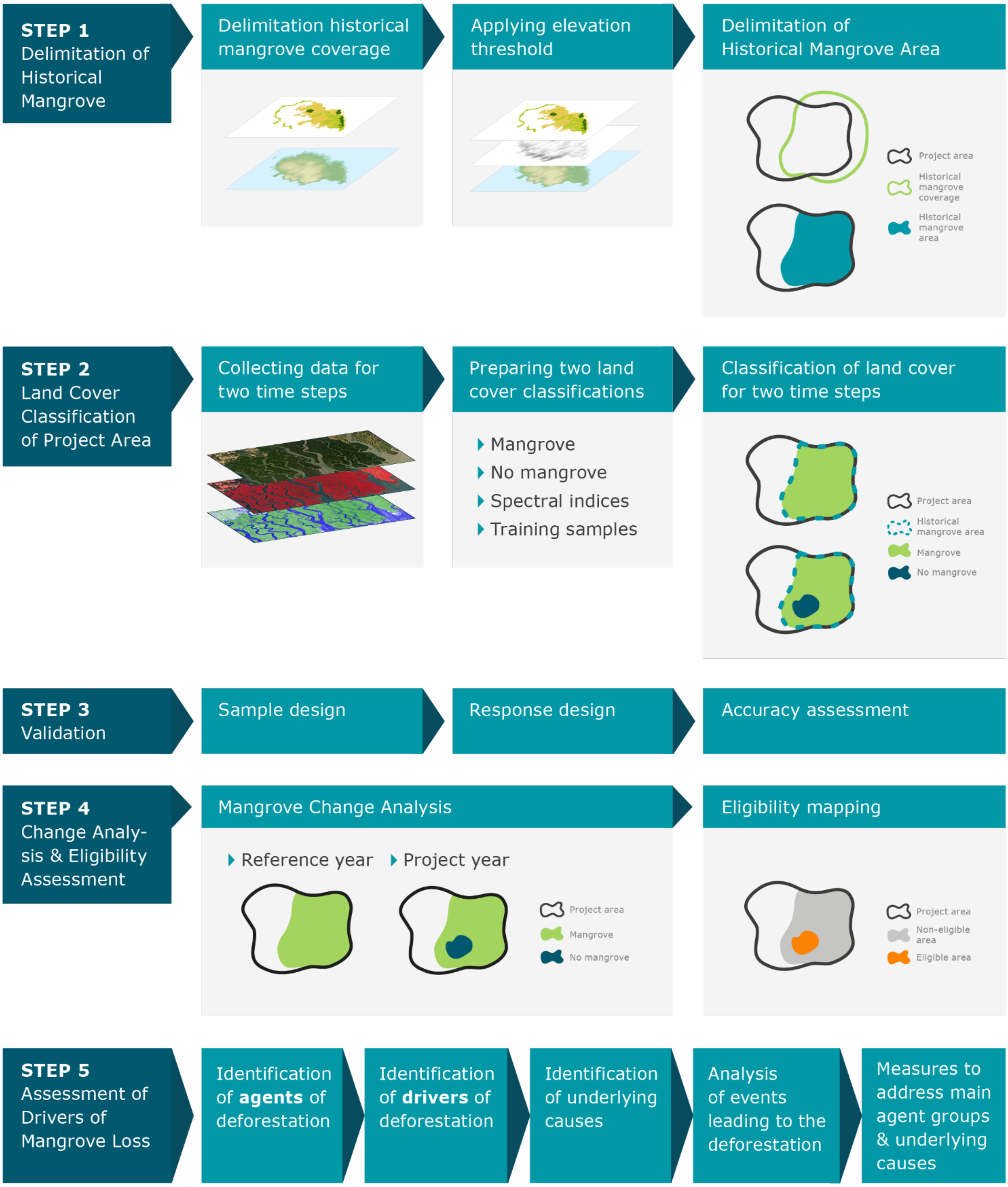

Figure A.1.1. General framework for the eligibility analysis for mangrove deforestation and degradation, including the historical analysis and identification of drivers of mangrove degradation

Step 1.2: Elevation threshold to delimitate mangrove habitat

A1.1.4 | When the project developer conducts their own land cover classification to delimitate the mangrove coverage in Step 1.1, it is necessary to use digital elevation model (DEM) data to distinguish historical mangrove area based on the topographic characteristics of mangrove habitat. It is recommended to use DEM data from the NASA Shuttle Radar Topography Mission (SRTM) 30m model. (Other data of higher resolution can be used with proper explanation provided.)

A1.1.5 | By reclassifying the DEM, the analysis then proceeds to generate and separate those areas with an elevation greater than 0 metres and less than 50 metres (0 < SRTM < 50).[28] A geo-referenced and reclassified raster layer from DEM-SRTM is obtained. Areas where the SRTM elevation exceeds 50 metres shall be masked and shall not be considered historical mangroves. It should be noted that the project developer can modify the elevation threshold (below 0 metres or above 50 metres) if the existence of mangrove cover at that altitude is justified.

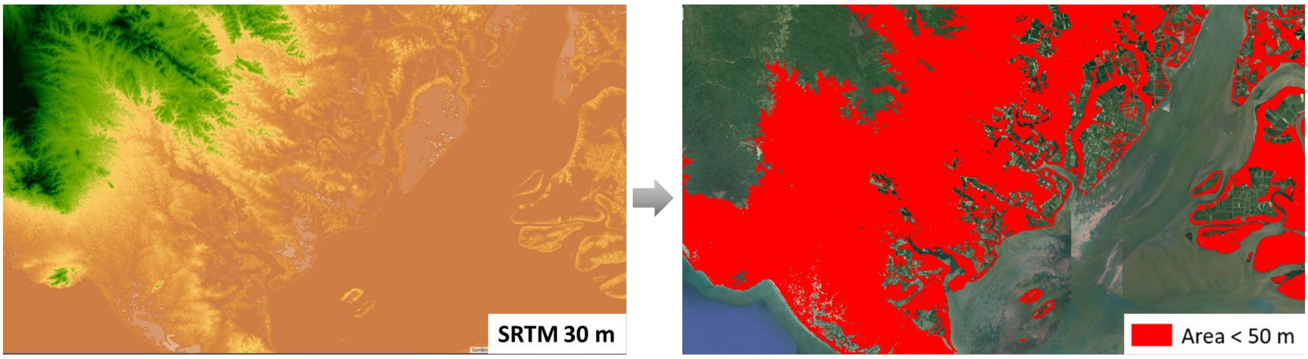

Figure A.1.2. Mangroves usually grow up to 50 metres above sea level. Image adapted from Saha et al. (2011).[29]

A1.1.6 | The initial historic mangrove coverage obtained in Step 1.1 using land cover classification shall be intersected with the binary elevation mask and the project area. The remaining area is called historic mangrove area. It may include one or several discrete areas.

A1.1.7 | Based on the historical mangrove mapping, any section of the project area that falls outside the historic mangrove area is not mangrove habitat and thus is not eligible.

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[28] A. R. Huete, "A soil-adjusted vegetation index (SAVI)," *Remote Sens. Environ.*, vol. 25, no. 3, pp. 295–309, Aug. 1988, doi: 10.1016/0034-4257(88)90106-X.

[29] A. K. Saha et al., "Sea level rise and South Florida coastal forests," *Clim. Change*, vol. 107, no. 1, pp. 81–108, Jul. 2011, doi: 10.1007/s10584-011-0082-0.

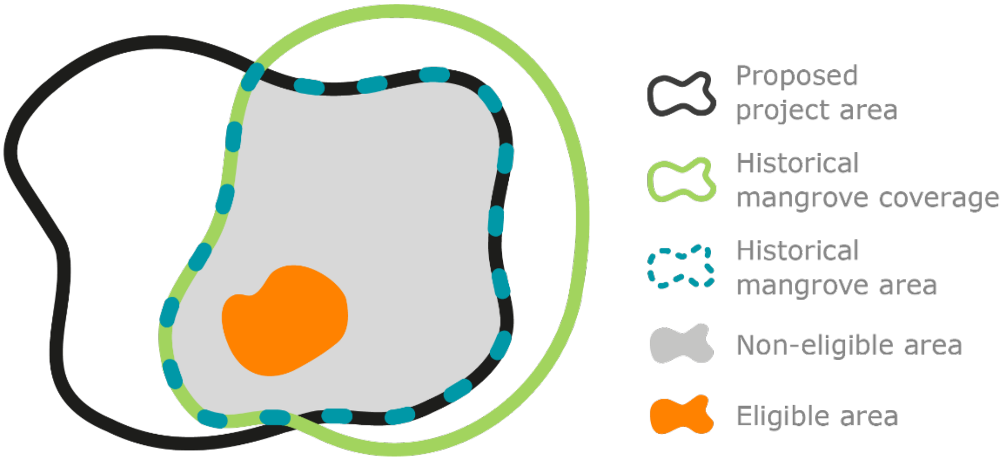

Figure A.1.3. Schematic visualisation of the historic mangrove area, defined as the historical mangrove coverage in the project area since at least 10 years prior to project start date

The box below details the steps necessary to delimitate the historical mangrove area:

Step 1: Delimiting historical mangrove area

Objective: Identify historical mangrove coverage of the project before the reference date.

Inputs:

- Vector layer of project area.
- Official maps, GMW data, or own land cover classification of at least 10 years prior to the project start date at the project location. The extent of this data is referred to as historical mangrove coverage.

Output: Vector layer of the intermediate historical mangrove area.

Step 2: Elevation threshold to delimitate mangrove habitat

Apply the elevation threshold to the historical mangrove extent to further delimitate the mangrove suitable areas. The exclusion based on topography is only necessary for historical mangrove coverage produced by the project developer.

Objective: Delimitate mangroves using an elevation range of mangrove habitat.

Inputs:

- DEM 30m (raster format).
- Historical mangrove area from Step 1.

Output:

- One binary raster mask with elevation between 0 and 50 metres above sea level in the initial historical mangrove area.

A polygon (vector file) enclosing mangrove habitat and outlining the final **historical mangrove area.**

Step 2: Land cover classification of the project area

A1.1.8 | The project developer shall identify and describe the land cover classes in the project area for the baseline scenario. The land cover classification (mangrove/no mangrove) is necessary to identify the project-related areas and to determine eligible areas based on the land cover changes in the baseline scenario.

A1.1.9 | Each stage of the methodological process carried out to obtain the land covers in the baseline scenario of the project area is described below.

Step 2.1: Data collection

A1.1.10 | Collect the data that shall be used to produce land cover and change information for the project area during the baseline scenario period. The analysis period is defined by the project start date and the reference date (10 years before the project start date).

A1.1.11 | The project developer shall collect geospatial data (e.g., remote sensing imagery or digital maps and external vector or imagery files) in order to (i) identify and quantify mangrove deforestation and (ii) identify drivers of mangrove deforestation.

A1.1.12 | This section outlines the criteria for acquiring remote sensing data as well as the key characteristics the data shall have. Optical sensor systems, such as Landsat, Sentinel-2, SPOT, ASTER, or other sensor data covering the relevant time period[30] shall be considered and shall meet the required criteria. It is mandatory to do this for at least two points in time: (1) at the project start date and (2) at the reference date (10 years prior to the project start date). Eligible timeframes for imagery acquisition for both timesteps are specified in Table A.1.1. The minimum spatial resolution required for all geospatial data collected is 30 metres. The use of satellite images with higher spatial resolutions (i.e., 10-20–metre resolution) is strongly recommended if they meet the replicability criteria[31] for monitoring. Datasets with spatial resolution lower than 30 metres are not eligible.

A1.1.13 | Collect remote sensing data with a cloud cover of less than 10% over the project area, even if there is more than 10% cloud cover in the whole scene (path/row). A cloud mask shall be created and then applied to the polygon/raster defining the project area. Note that any project area under

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[30] With Landsat, one can map change over time for three decades or more; with Sentinel, one can map starting approximately from 2015 onward.

[31] Replicability: Providing a consistent set of data with similar characteristics on a regular basis over a period.

clouds/shadows/image defects shall be masked out in land cover classification and conservatively assumed to be non-eligible area. For places with persistent cloud cover, it is recommended to use images outside of the rainy season. The project developer can prove the eligibility of areas under clouds/shadows/image defects by providing ground information through field visits, such as geo-referenced photographs. Images can be acquired for up to three months prior to the project start date. The project developer is allowed to create composite images making use of cloud-free pixels from different timesteps within the eligible timeframes specified in Table A.1.1. Composites must be accompanied by metadata and information about what imagery was included for their creation.

A1.1.14 | The project developer also shall collect higher-resolution data (pixel size < 5 x 5 m) from remote sensing sensors and/or from direct field observations for ground-truth validation for further analysis. For this purpose, the validation data must not have an acquisition date that deviates beyond +/- six months from the acquisition dates of the datasets being validated. Therefore, it is recommended to consider the availability of the validation data when the project developer collects data for land cover classification in this step.

A1.1.15 | In tabular format below, indicate the project start date and the oldest point in time that defines the period for the spatial analysis.

> One of the satellite missions that meets the minimum spatial resolution criteria is Landsat (Landsat TM, ETM+, OLI), which provides multispectral information with a spatial resolution of 30 m as of April 1997. For the purpose of this methodology, it is recommended that the project developers use atmospherically corrected images (L2A product) and multispectral coverage for Landsat 8-7-5 taken in the dry season of the project area with less than 10% of cloudiness in the project area.

Table A.1.1. Date criteria for spatial analysis

Date criteria for spatial analysis		
a.	Project start date (project scenario)	dd/mm/yyyy
b.	Reference date (10 years prior to the project start date)	dd/mm/yyyy
c.	Eligible range of dates for images at project start date	Up to 12 months prior to start date
d.	Eligible range of dates for images at reference date	Up to 12 months prior to reference date

Example:

Project X has a project start date of 12 March 2020. The reference date for the comparison is 12 March 2010. Thus, the range of eligible dates for the image at the project start date is from 12 March 2019 to 12 March 2020, while the range for eligible dates for the image at the oldest point in time is 12 March 2009 to 12 March 2010.

A1.1.16 | In tabular format below, indicate the information about the remote sensing sensor(s) that will be used.

Table A.1.2. Format to be filled out by the project developer

Type of remote sensor (satellite, radar, or airborne)	Sensor name	Resolution		Coverage	Cloud coverage over the project area	Acquisition date	Scene or point identifier	
		Spatial (meters)	Spectral (VIS, NIR, SWIN, TIR, other)	(km^2)	(%)	(dd/mm/yyyy)	Path/ latitude (DD)	Row/ longitude (DD)

Step 2.2: Defining the land cover mangrove class

A1.1.17 | The objective of this step is to identify and describe the land cover classes present in the project area at (i) project start date and (ii) reference date (10 years before project start date).

A1.1.18 | Using the data collected, divide the project area into areas representing land cover classes (related to mangroves).

A1.1.19 | The following criteria shall be used to define the land cover classes in the project area, i.e., mangrove and no mangrove.

a. The mangrove class shall represent mangrove forest canopies. This class can be located only in the historical mangrove area which was mapped earlier , considering topographic and other information.
b. The no mangrove class shall represent all land cover types other than mangrove forest canopies. If possible, the no mangrove class might be stratified into sub-classes according to IPCC land use and land cover categories used for national GHG inventories (e.g., cropland, grassland, wetland, settlement, and other land).

A1.1.20 | A description of each land cover class shall include criteria that are relevant for the discrimination of that class from all other classes. Criteria allowing a transparent definition of the boundaries of the land cover polygons of each class **SHALL BE SELECTED**.

A1.1.21 | List the resulting final land cover classes as shown in Table A.1.3.

Table A.1.3. List of all land cover classes existing at the project start date within the project area

Class identifier		Description (including criteria for boundary definition)
ID	Name	
1	Mangrove	[to be added as per project conditions]
2	No mangrove (or stratified into more sub-classes)	[to be added as per project conditions]

Step 2.3: Image pre-processing

A1.1.22 | This step refers to the preparation of optical satellite images prior to their classification.

A1.1.23 | Pre-processing[32] typically includes general procedures such as:

a. *Geometric corrections* to ensure the right position of a single image or to ensure that several images in a time series overlay properly to each other and to other datasets used in the analysis (i.e., for land cover change detection). The average location error between two images shall be < 1 pixel.

b. *Cloud and shadow removal* by filling masked areas with portions of cloud-free images closest in time to the original or using additional sources of data (e.g., radar, aerial photographs, field surveys). If the project developer builds cloud-free composites,[33] images of the date range proposed in Table A.1.3 shall be considered.

c. *Radiometric corrections* may be necessary (depending on the change detection technique used) to ensure that similar objects have the same spectral response in multitemporal datasets (i.e., Landsat product L2A).

[32] http://www.geo-informatie.nl/courses/gima_rs/Day%204/GIMA%20Preprocessing.pdf

[33] http://openmrv.org/en/web/guest/-/modules/mrv/modules_1/image-mosaic-composite-creation-for-landsat-and-sentinel-2-in-google-earth-engine

d. *Reduction of haze*, as needed.

A1.1.24 | This step applies to images from both the baseline scenario and the project start date. A project developer shall document the pre-processing procedure (geometric and radiometric correction) in the PDD.

Summary of Step 2.3: Image pre-processing

Objective: Acquire and prepare satellite images in the project area prior to their classification.

Input: All remote sensing data collected in Step 2.1 in the project area.

Output: Geo-referenced images of the project area for two time points (the project start date and 10 years prior to the project start date), mostly cloud-free or with a maximum of 10% cloudiness over the project area.

Step 2.4: Land cover classification

A1.1.25 | This stage seeks to identify the land cover classes present in the project area for the two points in time.[34] It is recommended to use a supervised classification method for land cover classification. In supervised classification, the analyst defines representative samples (training areas) for each of the classes to be identified in the image. With this key step, the analyst controls the categories and can tailor them to suit a specific purpose and geographic region. If a class (mangrove or no mangrove) is not identifiable using training dataset at one of the timesteps within the project area, this class shall not be considered further in the classification for this year.

Step 2.4.1: Spectral indices

A1.1.26 | Spectral indices are calculations based on spectral reflectance values of multispectral imagery, such as the ratio between reflection of red and near-infrared wavelengths. Several vegetation indices have been used to map mangrove forests using satellite imagery.

A1.1.27 | This methodology recommends generating the following vegetation indices: Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Normalized Difference Moisture Index (NDMI), Soil Adjusted

[34] (1) At the project start date (project scenario) and (2) 10 years prior to the project start date (baseline scenario)

Vegetation Index (SAVI), Modified Normalized Difference Water Index (MNDWI), Green Chlorophyll Vegetation Index (GCVI), and band ratios.

A1.1.28 | These indices shall be calculated from geo-referenced images (output from Step 2.3) (i.e., images with visible and infrared bands are requested, such as Landsat 8 and Sentinel-2) for two points in time: (1) at the project start date and (2) 10 years prior to the project start date (reference date).

A1.1.29 | One (or if it leads to improved classification, more than one) spectral index shall be added as an additional band to the geo-referenced images generated as outputs in Step 2.3 (which will later be used for the land cover classification).

Table A.1.4. List of indices derived from an optical image for the detection and classification of mangrove cover

Index	Description	Equation
Normalized Difference Vegetation Index (NDVI)	The NDVI is calculated as a ratio between the reflectance in the electromagnetic spectrum of red (R) and the reflectance in the near-infrared (NIR).[35] The equation shows the calculation of the NDVI for any sensor; in addition, this index is used by Lu & Wang (2021)[36] and Lagomasino (2019)[37] for the timely mapping of large-scale mangroves.	$NDVI = \frac{(\rho_{NIR} - \rho_R)}{(\rho_{NIR} + \rho_R)}$
Normalized Difference Moisture Index (NDMI)	The NDMI considers the reflectance values in bands SWIR 2 and green of the Landsat images used to highlight the spectral absorption peaks. In theory, NDMI $\in [-1, 1]$, ranges are extended by the negative	$NDMI = \frac{(\rho_{SWIR2} - \rho_{Green})}{(\rho_{SWIR2} + \rho_{Green})}$

[35] T. N. Carlson and D. A. Ripley, "On the relation between NDVI, fractional vegetation cover, and leaf area index," *Remote Sens. Environ.*, vol. 62, no. 3, pp. 241–252, Dec. 1997.
doi: 10.1016/S0034-4257(97)00104-1.

[36] Y. Lu and L. Wang, "How to automate timely large-scale mangrove mapping with remote sensing," *Remote Sens. Environ.*, vol. 264, p. 112584, Oct. 2021.
doi: 10.1016/j.rse.2021.112584.

[37] D. Lagomasino *et al.*, "Measuring mangrove carbon loss and gain in deltas," *Environ. Res. Lett.*, vol. 14, no. 2, p. 025002, Jan. 2019. doi: 10.1088/1748-9326/aaf0de.

	reflectance values of certain water pixels.[38]	
Soil Adjusted Vegetation Index (SAVI)	The SAVI is a modified version of the NDVI that is designed to minimise the soil brightness influence. The default adjustment factor L is 0.5.[39]	$SAVI = \frac{(1+L)(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + \rho_{Red} + L)}$
Enhanced Vegetation Index (EVI)	EVI uses the blue band to reduce the impact of atmospheric effects, and it is more sensitive in high biomass regions compared with NDVI and SAVI.[40] L=1, C_1 = 6, C_2 = 7.5, G=2.5 can be used.	$EVI = G \frac{(\rho_{NIR} - \rho_{Red})}{(\rho_{NIR} + C1 \times \rho_{Red} - C2 \times \rho_{Blu}}$
Modified Normalized Difference Water Index (MNDWI)	MNDWI can enhance open water features while suppressing and even efficiently removing accumulated dirt noise as well as vegetation and ground noise.	$MNDWI = \frac{(\rho_{Green} - \rho_{SWIR})}{(\rho_{Green} + \rho_{SWIR})}$
Green Chlorophyll Vegetation Index (GCVI)	The GCVI reflects the leaf area and chlorophyll concentration of the plant.[41]	$GCVI = \frac{(\rho_{NIR})}{(\rho_{Green})} - 1$
Band ratio indices	This methodology considers that the ratio of two bands eliminates much of the effect of illumination in the analysis of spectral differences. For this reason, it proposes the use of these three ratios commonly used for the separation of plant covers.	$Ratio\ 1 = \frac{\rho_{SWIR1}}{\rho_{NIR}}$ $Ratio\ 2 = \frac{\rho_{SWIR2}}{\rho_{SWIR1}}$ $Ratio\ 3 = \frac{\rho_{NIR}}{\rho_{SWIR2}}$

A1.1.30 | A useful and complementary tool to find indices for a required application adapted to any selected sensor is the Index Database, where there is a complete database of remote sensing indices and satellite sensors.

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[38] T. Shi, J. Liu, Z. Hu, H. Liu, J. Wang, and G. Wu, "New spectral metrics for mangrove forest identification," *Remote Sens. Lett.*, vol. 7, no. 9, pp. 885–894, Sep. 2016.

doi: 10.1080/2150704X.2016.1195935.

[39] A. R. Huete, "A soil-adjusted vegetation index (SAVI)," *Remote Sens. Environ.*, vol. 25, no. 3, pp. 295–309, Aug. 1988, doi: 10.1016/0034-4257(88)90106-X.

[40] M. Schultz *et al.*, "Performance of vegetation indices from Landsat time series in deforestation monitoring," *Int. J. Appl. Earth Obs. Geoinformation*, vol. 52, pp. 318–327, Oct. 2016, doi: 10.1016/j.jag.2016.06.020.

[41] T. Shi, J. Liu, Z. Hu, H. Liu, J. Wang, and G. Wu, "New spectral metrics for mangrove forest identification," *Remote Sens. Lett.*, vol. 7, no. 9, pp. 885–894, Sep. 2016, doi: 10.1080/2150704X.2016.1195935.

A1.1.31 | Although these indices, especially NDVI and NDMI, are usually used for the detection of mangroves, the project developer can select other indices that adjust to the characteristics of the sensor, spatial context, and time.

A1.1.32 | Selection of vegetation indices other than those listed in this methodology must be justified and supported by data (peer-reviewed literature). Likewise, it will be requested that the selected indices must be correctly explained in the document in the PDD verification and replicability.

Summary of Step 2.4.1: Spectral indices

Objective: Calculate the spectral indices more suitable for land cover classification of remote sensing imagery in the project area.

Inputs: Geo-referenced satellite imagery (output from Step 2.3) for two time points (the project start date and the reference date).

Outputs:

1) For each spectral index, two raster images: one for each of the two time points (the project start date and 10 years prior to the start date).

2) Two geo-referenced images (with spectral indices added as additional bands), one for each of the two time points (the project start date and 10 years prior to the start date). Maximum of 10% cloudiness over the project area.

Step 2.4.2: Training samples

A1.1.33 | This step requires collecting training data that is essential for supervised classification. To do this, the geo-processed satellite image shall be used as an initial input. It is necessary for the project developer to have prior knowledge of the project area, either through field experience or secondary information such as official documents. A set of training samples shall be generated for each of the two time points analysed as conditions, for the different acquisitions may differ.

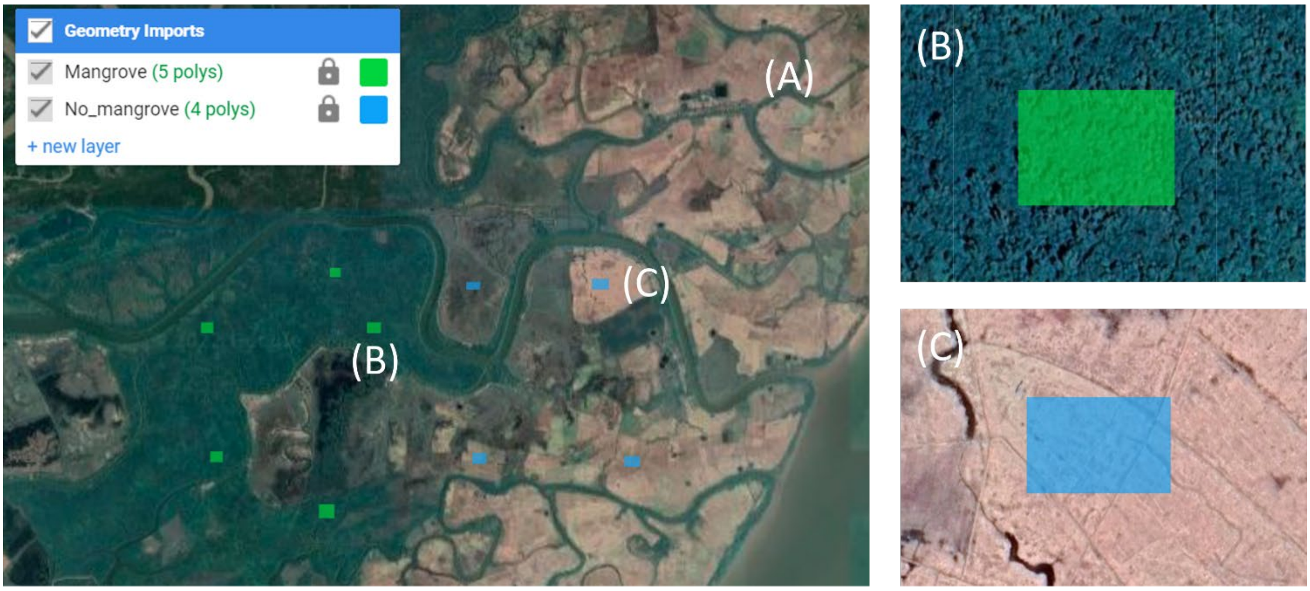


Figure A.1.5. Collection of training samples over the satellite image. Examples of mangrove cover in Rakhine, Myanmar. (A) High-resolution Google Earth (2022). The enlarged images represent examples of (B) mangrove, (C) no mangrove.

A1.1.34 | The following criteria[42] shall be used to collect training samples on the digital image of the project area:

a. *Classes:* The minimum classes shall be two: mangrove and no mangrove.
b. *Size:* Each training sample shall be large enough to provide accurate estimates of the properties of each class.
c. *Number:* Each category or each spectral sub-class shall be represented by an adequate number (10-20 at a minimum) of training areas to ensure that the spectral properties of each category are represented.

A1.1.35 | A polygon vector file shall be provided for all training samples collected and used for land cover classification.

[42] J. B. Campbell and R. H. Wynne, *Introduction to Remote Sensing*, Fifth. 2011.

Summary of Step 2.4.2: Training samples

Objective: Identify and collect training samples for land cover supervised classification.

Area of analysis: Project area

Inputs: Geo-referenced satellite image (output of Step 2.3) at the project start date.

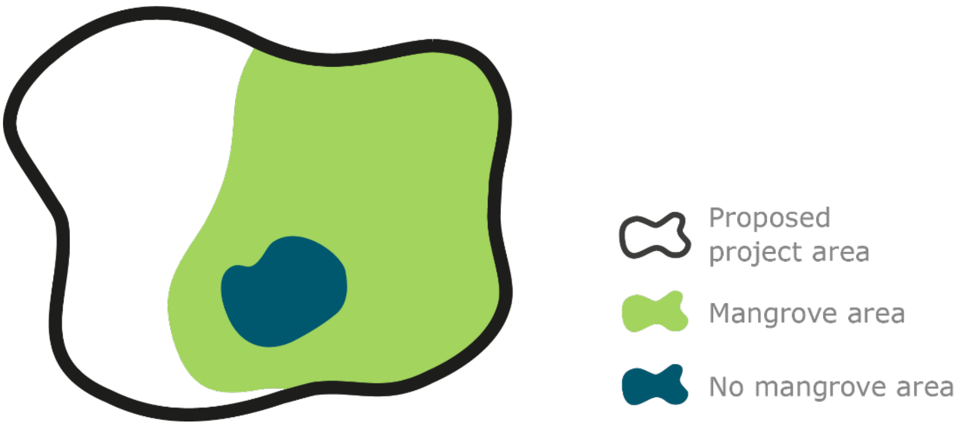
Output: Two vector files, each containing the training samples from the geo-referenced images in each of the two time points (the project start date and 10 years prior to the start date).

Step 2.4.3: Classification algorithm

A1.1.36 | Based on the training samples selected on the image, a classification algorithm such as Random Forest shall be used.[43] Other methods can also be used if their classification accuracy is within the specified parameters in Step 3 (Validation).

A1.1.37 | The project developer shall take the training samples for the land cover classes (from Step 2.4.2) on the geo-referenced satellite images and the spectral indices layers (from Step 2.4.1) as inputs to train the classifier and then apply the trained classifier to the image data to obtain the classified maps with the land cover classes.

A1.1.38 | After the land cover classification step, the project developer shall have produced a land cover map containing mangrove and no mangrove classes in the project area for the two timesteps required: the reference date and the project date. The figure below shows a schematic example of a land cover classification result inside the project area.



[43] Developed by Adele and Richard Cutler of Utah State University

Figure A.1.6. Visualisation of land cover classification results with two classes: mangrove and no mangrove

Summary of Step 2.4.3: Classification algorithm

Objective: Land cover classification of geo-processed images (from Step 2.3)

Input: Geo-referenced satellite image with vegetation indices added as additional spectral bands (output of Step 2.4.1) and training samples (output of Step 2.4.2) and a classification algorithm.

Output: Two classified rasters (one for each of the two time points analysed), each with two land cover classes: mangrove and no mangrove.

Step 3: Validation

A1.1.39 | It is necessary to validate each of the land cover rasters produced in the previous steps:

a. Land cover classification of project start date (output of Section 3.6.2, Step 2.4)
b. Land cover classification of 10 years prior to the project start date (output of Section 3.6.2, Step 2.4)

A1.1.40 | The project developer shall report the following accuracy metrics:

a. Total accuracy is the proportion of area mapped correctly.
b. User accuracy for each class is the proportion of mapped areas (of a particular class) correctly classified according to the reference data.
c. Producer accuracy for each class is the proportion that is of a particular category in the field that is also mapped as that category.

A1.1.41 | The minimum overall accuracy of the land cover map must be 90% for the classes mangrove and no mangrove. The minimum classification accuracy (user's accuracy and producer's accuracy) of each class or category in the land cover maps must be 90%.

A1.1.42 | At this stage, the methodology developed by Oloffson (2013)[44] and Oloffson (2018)[45] for the accuracy assessment in three stages is presented

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[44] P. Olofsson, G. M. Foody, S. V. Stehman, and C. E. Woodcock, "Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation," *Remote Sens. Environ.*, vol. 129, pp. 122–131, Feb. 2013, doi: 10.1016/j.rse.2012.10.031.

[45] P. Olofsson, "6.08 - Accuracy and Area Estimation," in *Comprehensive Remote Sensing*, S. Liang, Ed. Oxford: Elsevier, 2018, pp. 128–135. doi: 10.1016/B978-0-12-409548-9.10382-3.

and shall be applied by the project developer: (1) the sampling design, (2) the response design, and (3) the accuracy assessment.

A1.1.43 | The sampling design addresses conceptual aspects to choose a subset of units from the region of interest. The response design indicates the main points to consider in determining whether the map and reference data are appropriate and suitable for validation. Finally, the accuracy assessment section includes methods for estimating thematic accuracy.

A1.1.44 | The project developer can perform validations through platforms that enable viewing high- and medium-resolution satellite images and that conduct the sampling process, such as Collect Earth[46] in conjunction with Google Earth, Bing Maps, etc.

Step 3.1: Sample design

A1.1.45 | The main recommendation is to consider a probabilistic sampling design. The two conditions that define probabilistic sampling are (1) the probability of inclusion must be known for each unit selected in the sample, and (2) the probability of inclusion must be greater than 0 for the entire region of interest. One of these methods is stratified random sampling (SRS).

Table A.1.5. Description of the stratified random sampling method

Sample design	Description
SRS	SRS is a method of sampling that involves dividing a population into smaller groups called "strata." The strata are organised based on the shared characteristics or attributes of the members in the group. SRS is advantageous when there are small map categories because it gives adequate representation to each stratum, especially in the rare classes. The strata can be the land cover classes: mangrove class, no mangrove class, and/or other classes if applicable.

Table A.1.6. Classes of interest to evaluate

Class	Name
1	Class 1

[46] Collect Earth is a tool that enables data collection through Google Earth. https://www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/en/c/411199/

2	Class 2

A1.1.46 | Determination of sample size: The project developer shall select adequate validation samples to make sure the validation accuracy is representative of the total land cover classification map. It is recommended to select a total of sample size that occupies no less than 2% of the whole area.

$$n \approx A * 2\%$$

n = Total number of sample units (in pixel)

A = Total area in project area (in pixel)

Example:

Stratum	$A_{p,i}$(pixels)	$A_{,i}$(ha)
Mangrove	22,222	2,000
No mangrove	13,333	1,200
Total	35,555	3,200

$n = 35{,}555 \times 2\% \approx$ 700 (pixel)

A1.1.47 | Assignment of sample sizes in the strata: After determining the total sample size, the allocation in each stratum can be calculated proportionately:

$$n_i = n * Wi$$

Where:

n_i = Stratum *i* sample size

n = Total sample size

W_i = Weight of each class with respect to the total area of study

A1.1.48 | Note that if this calculation results in a sample size that is insufficient (less than 2%) in a rare class, it is recommended to first allocate an adequate sample size in the rare class and then distribute the remaining samples proportionately in other classes. Also, the classification of the minimum sample size in each class should be at least 10 times the number of classes in the land cover map. For instance, if there are two classes in the map (mangrove and no mangrove), the minimum number of samples in each class should be 20.

Table A.1.7. Conceptual example of stratum in land cover map with counts and weights

Stratum	$A_{p,i}$(pixels)	A_i(ha)	W_I	Distribution sample points amongst strata

Class1	$A_{p,1}$	A_1	A_1/A_T	n_1
Class2	$A_{p,2}$	A_2	A_2/A_T	n_2
Total	$A_{p,T}$	A_T	1	n_T

n = Number of sample units (raster map vs. reference data)

A = Total area in each coverage

Wi = Weight of each coverage with respect to the project area

A1.1.49 | The corresponding number of samples of each stratum shall be distributed randomly within the strata on the map classification. In the recommendation above, the sample unit is pixel. The project developer can also use other sample units, such as polygon or block that consists of multiple pixels. However, the total area within the samples should follow the same criteria (2% of the whole area).

A1.1.50 | The validation samples must not be identical to the training samples used for land cover classification.

Example:

Stratum	$A_{p,i}$ (pixels)	$A_{,i}$ (ha)	W_i	Distribution sample points amongst strata
Mangrove	22,222	2,000	0.62	343
No mangrove	13,333	1,200	0.38	210
Total	35,555	3,200	1	700

n_i mangrove = 700*0.62 = 434

n_i No mangrove = 700*0.38 = 210

Step 3.2: Response design

A1.1.51 | After the allocation and selection of samples, the reference labels in each sample unit shall be assessed using validation data.

Step 3.2.1: Validation data

A1.1.52 | Some possible reference data include field data, inventory data, orthorectified aerial photographs, lidar, and high-resolution satellite imagery. If on-the-ground information is not available, it is suggested to use remote sensing images. Validation requires the use of images with a higher spatial resolution (smaller pixel size) than those used in Step 2 (preferably less than or equal to 5 x 5 m pixels), such as the DigitalGlobe/Maxar, Planet Scope, Norway's International Climate and Forests Initiative (NICFI) data, stereophotogrammetric data (31 cm–5 m), or Google Earth images. If higher resolution images are not available, the same images used for classification can be used; however, the process for obtaining reference data must be more accurate than the process used for map classification, for instance, manual interpretation of sample units.

A1.1.53 | Validation data must not have an acquisition date that deviates beyond +/- six months from the acquisition dates of the datasets being validated. Describe the type of data, the coordinates (latitude and longitude in decimal degrees), and the sampling design used to collect them.

Example:

For the validation of a Landsat 8 classification map of December 2021 (image of the project start date), RapidEye images (5 x 5 m resolution) of October 2021 (acquisition date) are acceptable for validation. In the event that no higher resolution images or secondary data are found for the 10 years before the start of the project, the base images used for classification will be used.

Step 3.2.2: Labelling the data reference

A1.1.54 | After the validation data is prepared and the validation sampling areas are selected, the next step is to label the land cover classes in each sampling unit, which constitute the reference classification. The project developer shall provide a description of how to translate the reference data to get the reference land cover class labels, such as interpretation keys when visual assessment is used. In cases where the sampling unit on the validation data is not homogeneous and there is more than one class in reality (since the resolution of validation data is higher), the project developer shall provide a description of how to achieve the final reference classification.

Step 3.3: Accuracy assessment

A1.1.55 | After determining the sample size, distribution, and interpretation, the next step is to validate the map (ground-truth validation) to assess the accuracy.

A1.1.56 | Based on the calculated sample size per strata, the project developer shall develop a confusion matrix to show the count of correctly and incorrectly classified samples at the level of strata.

Table 7.8. Confusion matrix with counts and totals

Stratum	1	2	…	j	Total
1	n_{11}	n_{12}	…	n_{1j}	n_{1+}

2	n_{21}	n_{22}	…	n_{2j}	n_{2+}
.	.	.	.	.	.
.	.	.	.	.	.
	.	.			
i	n_{i1}	n_{i2}	…	n_{ij}	n_{i+}
Total	n_{+1}	n_{+2}	…	n_{+j}	n

The rows represent the categories of the classification map, and the columns represent the categories of reference data.

Example:

Confusion matrix

		Reference data		Total
		Mangrove	No mangrove	
Map	Mangrove	440	0	440
	No mangrove	5	255	260
Total		445	255	700

A1.1.57 | With the confusion matrix in Table A.1.8, the thematic precisions will be calculated with:

a. User's accuracy: $U_i = \frac{n_{ii}}{n_{i+}}$

b. Producer's accuracy: $P_j = \frac{n_{jj}}{n_{+j}}$

c. Overall accuracy: $O = \frac{\sum_{i=1}^{i} n_{ii}}{n}$

Example:

		Reference data		Total	User's	Overall
		Mangrove	No mangrove			
Map	Mangrove	440	10	450	0.98	0.98
	No mangrove	5	255	260	0.98	
Total		445	265	710		
Producer´s		0.99	0.96			

- User's accuracy (mangrove): $\mathrm{U}_i = \frac{440}{450} = 0.98$
- Producer's accuracy (mangrove): $\mathrm{P}_j = \frac{440}{445} = 0.99$

A1.1.58 | The selection of the method for validation assessment is based on the data available for training and validation purposes. In all cases, a detailed description of the data acquisition and sampling methodology used in the reference must be included in the PDD.

A1.1.59 | The user's accuracy and the producer's accuracy for each land cover class, as well as the overall accuracy of the whole map product, must be greater than 90%. If the accuracy of a class or category is less than 90%, consider reevaluating or modifying the classification processes, incorporating spectral indices, and/or adding training samples that help the separation of classes.

Summary of Step 3: Validation

Objective: Accuracy assessment of the land cover classified rasters.

Inputs: Two land cover classified rasters generated in Step 2, validation data (such as high-resolution image), reference point distribution.

Output: Two confusion matrixes (one for each classified raster) indicating overall accuracy of land cover classification, producer's accuracy, and user's accuracy.

Step 4: Land cover change analysis and land eligibility assessment

A1.1.60 | This final procedure analyses land cover change between reference date and project start date to determine and quantify eligible and non-eligible areas within the project area.

A1.1.61 | As required before in Step 1, the project area that falls outside of mangrove coverage (historic mangrove area) shall be considered as non-eligible. Therefore, **the change analysis shall be conducted within the historic mangrove area**.

A1.1.62 | Each classified raster shall have at least two land cover classes (as defined in Step 2.2). The project developer shall conduct change detection between the classified raster at the reference date (with two land cover classes) and the raster at the project start date. Change detection shall result in a new raster with two classes: eligible and non-eligible areas.

A1.1.63 | Eligible areas are those sections of the project area that are classified as **no mangrove** at the project start date AND are classified as **either one of the following** 10 years before the project start date:

a. **Mangrove**: Only when the project developer can prove that the change from mangrove to no mangrove is not a result of an intention to implement a carbon credit project. Eligibility of areas that were deforested in the baseline period shall follow the GS4GG LUF Activity Requirements General Eligibility Criteria, or

b. **No mangrove**: Eligible for mangrove reforestation.

A1.1.64 | In retroactive projects, an eligible area could be **mangrove** at the project listing date and **no mangrove** 10 years before the project start date.

A1.1.65 | The project developer shall follow the guidance in Table A.1.9 and Figure A.1.7 for each scenario.

Table A.1.9. Land eligibility based on initial and current land cover

Project type	Land cover 10 years before project start date	Land cover at project start date	Eligibility	Condition
Regular project	Mangrove	Mangrove	Not Eligible	N/A
		No mangrove*	Eligible	Eligibility pending Gold Standard approval of results from 3.6.5: Assessment of drivers of mangrove loss.

	No mangrove	Mangrove	Not eligible	N/A
		No mangrove*	Eligible	No mangrove area is eligible
	No mangrove**	No mangrove**	Not Eligible	N/A

Notes:

* The **no mangrove** class within the historical mangrove coverage represents deforested mangroves. Deforested mangroves can be defined using the national forest definition[47] or by the most recent IPCC guidelines.[48]

** The **no mangrove** class outside of the historical mangrove area and reference area are not eligible.

Figure A.1.7. Eligible areas

Summary of Step 4: Eligible areas

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[47] United Nations Framework Convention on Climate Change, "CDM: Full list of DNAs," 2021. https://cdm.unfccc.int/DNA/bak/index.html.

[48] P. Olofsson, G. M. Foody, S. V. Stehman, and C. E. Woodcock, "Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation," *Remote Sens. Environ.*, vol. 129, pp. 122–131, Feb. 2013, doi: 10.1016/j.rse.2012.10.031.

P. Olofsson, "6.08 - Accuracy and Area Estimation," in *Comprehensive Remote Sensing*, S. Liang, Ed. Oxford: Elsevier, 2018, pp. 128–135. doi: 10.1016/B978-0-12-409548-9.10382-3.

Objective: Identify the eligible areas inside the project area.

Inputs: Land cover raster maps for the project start date and the reference date.

Output: One raster file and one vector (polygon) file with two land cover classes: eligible areas and non-eligible areas.

Step 5: Assessment of drivers of mangrove loss

A1.1.66 | Determining the agents of mangrove deforestation and the drivers and underlying causes (what drives the land use change decisions) is necessary for two main reasons: (1) basis of proving that deforestation was caused by the drivers and not purposely for developing the carbon project and (2) for ensuring longevity of the mangrove plantation.

A1.1.67 | Using an inclusive, participatory, multi-stakeholder consultation approach, projects shall identify the main agents of deforestation (e.g., loggers, farmers, poachers) and their relative importance in relation to the extent of the historical land use and land cover (LULC) change.

A1.1.68 | The resulting maps from the previous sub-sections can be used to identify the location and extent of the LULC change. Additionally, through the multi-stakeholder approach, field-based and participatory mapping together with the stakeholders involved in the project shall be conducted to identify the agents of deforestation and their relative importance.

A1.1.69 | The analysis of drivers and underlying causes is performed using the following sub-steps.

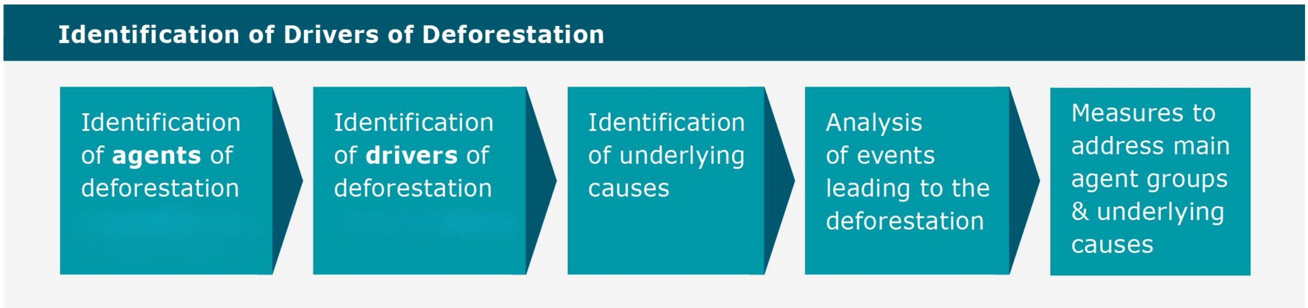

Figure A.1.85: Identification of drivers of deforestation

Step 5.1: Identification of agents of deforestation (who deforests mangroves)

A1.1.70 | The main agent groups of deforestation and their relative importance shall be identified. In order to do so, use existing studies, the resulting maps, expert consultation, field surveys, and other verifiable sources of information.

A1.1.71 | ***Output for Step 5.1:*** For each identified agent group, provide the following information:

a. Name of the main agent group(s) or agent(s) of mangrove deforestation.
b. Short description of the agents in terms of social, economic, cultural, and other relevant characteristics. The description must be limited to the aspects that are relevant for understanding the reasons behind the agents' deforestation activities.
c. Brief assessment of the most likely development of the population size of the identified main agent groups in the project area.
d. Statistics on historical deforestation attributable to each agent of deforestation.

Step 5.2: Identification of drivers of deforestation

A1.1.72 | After the agents of deforestation have been identified, the factors that led to the land use change shall be determined and analysed as well. These factors comprise the immediate causes of deforestation. Once the changes in the deforested areas are identified, it is crucial to understand the process dynamic and the drivers that led to the deforestation.

A1.1.73 | A driver is considered as an external factor or phenomenon that induces a change in the natural and phenological cycle of an ecosystem with recognisable effects.[49] Triggers of deforestation, such as erosion, natural hazards, climate change events, non-productive conversion, settlements, aquaculture, agriculture, and illegal logging, are the most frequent in mangrove deforestation. Those drivers are detectable in the time series through the temporal profiles when sudden changes are identified in the spectral trajectory along the time. Time series are capable of identifying the magnitude and the time of the change but not the circumstances or the drivers that cause the change.

A1.1.74 | Below are some considerations for use of land cover change analysis with remote sensing techniques. The LULC is the conversion of different land use types and is the result of complex interactions between humans and the physical environment. It is possible to establish a model to predict the trends of land use patterns in a certain period through the study of past land use changes, which provide a basis to describe the driver's effects. Therefore, accurate land cover change information is necessary for understanding and assessing LULC changes.

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[49] S. R. Phinn, D. Stow, J. Franklin, L. Mertes, and J. Michaelsen, "Remotely Sensed Data for Ecosystem Analyses: Combining Hierarchy Theory and Scene Models," *Environ. Manage.*, vol. 31, no. 3, pp. 0429–0441, Mar. 2003, doi: 10.1007/s00267-002-2837-x.

A1.1.75 | Two kinds of driver variables shall be identified:

1. Driver variables that describe the **quantity** (in hectares) of the deforestation, including the following, but not limited to:
    - Population density
    - Prices of agricultural products
    - Prices of timber-based products
    - Rural wages
    - Supply and coverage of energy resources
    - Cultural preferences (e.g., fuel wood for smoking fish)
    - Weak or poor governance
2. Driver variables that describe the **location** of the deforestation, including the following, but not limited to:
    - Proximity to markets
    - Proximity to existing settlements
    - Proximity to protected conservation areas
    - Proximity to infrastructure
    - Proximity to agriculture
    - Proximity to previously deforested mangrove areas
    - Biophysical variables that can serve as indicators for agricultural expansion (e.g., soil fertility, rainfall)

A1.1.76 | Quantitative drivers described in the preceding section (A1.1.75) are complex interactions of social, economic, political, cultural, and technological processes that can occur far from areas exposed to deforestation in mangroves. Likewise, these causes constitute the basis or scenario in which the direct causes develop and may be related to national or local circumstances. On the other hand, paragraph 2 of the preceding section (A1.1.75) is related to the direct variables that not only allow determination of the location of deforestation but also contribute to the construction of future scenarios, risk maps, and vulnerability of deforestation of mangroves. Its use for emphasising the areas of communal work and greater attention is crucial.

Each identified key driver variable provides information about its likely future development by providing any relevant source of information.

A1.1.77 | ***Output for Step 5.2:*** For each of these two kinds of variables:

a. List the main key driver variables affecting the quantity of mangrove deforestation. Provide evidence to support the findings.
b. List the main key driver variables affecting the location of mangrove deforestation. Provide evidence to support the findings.
c. Describe how each of the identified drivers affects the identified agents (Step 5.1):

i. in the 10-year period prior to project start date, and
ii. at project start date, and
iii. in the future in a without-project scenario.

d. briefly describe the project measures that will be implemented to address them, as applicable.

Step 5.3: Identification of underlying causes

A1.1.78 | The decisions made by the agents of deforestation were prompted by a broader set of influences classified as underlying causes, such as the following:

- Poverty
- Property regulations
- Population pressure
- Land use policies and implementation
- Governance

A1.1.79 | ***Output for Step 5.3:*** For each of these two kinds of variables:

a. List the main underlying causes affecting the quantity of mangrove deforestation. Provide evidence to support the findings.
b. List the main underlying causes affecting the location of mangrove deforestation. Provide evidence to support the findings.
c. Describe how each of the identified underlying causes affects the identified agents (Step 5.1):
   i. in the 10-year period prior to project start date, and
   ii. at project start date, and
   iii. in the future in a without-project scenario.
d. For each identified underlying cause, provide information about its likely future development by providing any relevant source of information.
e. For each identified underlying cause, briefly describe the project measures that will be implemented to address them, as applicable.

Step 5.4: Analysis of events leading to the deforestation

A1.1.80 | Based on the previous steps and historical data collected, analyse the relations amongst the main agent groups, key drivers, and underlying causes. Provide explanation on chronology of events that in general has led to and most likely will lead to deforestation. Consult local experts and stakeholders, peer-reviewed literature, and other sources of information, as necessary. Include in the PDD a summary of the results of this analysis.

Step 5.5: Measures to address main agent groups and underlying causes

A1.1.81 | Long-term success of a mangrove reforestation project depends on great measures for addressing mangrove loss. If left unaddressed, agents/drivers/underlying causes of mangrove loss will likely undermine the Sustainable Development Goal (SDG) 13 impacts of a project, both during its crediting period and after (permanence). Therefore, it is reasonable for mangrove reforestation projects to address mangrove loss (to the extent of their capabilities and possibilities). Results from actions and activities that aim at reducing mangrove loss must be reported as positive SDG impacts other than SDG 13.

A1.1.82 | Recognising that individual projects are not able to fully address complex interactions between agents, drivers, and underlying causes, projects are requested to do the following.

A1.1.83 | Identify and define, in a participatory manner with project participants, concrete actions that will reduce mangrove loss over the project crediting period. Outputs from the participatory assessment shall be:

a. at least one agent, driver, and underlying cause that leads to mangrove loss, and
b. action(s) that the project can implement (according to its capabilities and possibilities) individually and/or in collaboration with project developers to address the identified agent(s), driver(s), and underlying cause(s) that led to mangrove loss agent, and
c. clear timeline for implementation of actions and activities, and
d. clear and transparent assignment of responsibilities amongst project and participants, and
e. clear and transparent communication of the benefits to participants arising from supporting actions that prevent/reduce forces of mangrove loss.

A1.1.84 | Define a quantitative baseline for the selected forces of mangrove loss.

A1.1.85 | Define key indicators to measure progress towards identified goal(s) against a baseline.

A1.1.86 | Define credible and conservative short-term (annual), medium-term (five-year), and long-term (end of crediting period) goals to measure performance of the project against reduction of forces of mangrove loss.

A1.1.87 | Develop an adaptive management plan to periodically revise performance of actions and activities and implement changes/improvements to achieve planned goals.

Summary of Step 5: Assessment of drivers of mangrove loss

Objective: Identify agents, drivers, and underlying causes of mangrove loss and define actions and activities to address them within the possibilities of the project.

Inputs: Outputs from Steps 5.1 through 5.4.

Output: A participatory, adaptive plan to implement actions to address mangrove loss within the capacity and possibilities of the project.

APPENDIX 2| Eligible Mangrove-Specific Soil Sampling Protocols

A2.1.1 | The mangrove-specific soil sampling protocols listed below are recommended under this methodology. Additional sampling protocols may be submitted to Gold Standard to be included in the list, subject to review and approval.

Table A.2.1. List of eligible mangrove-specific soil sampling protocols

Name of protocol	Reference	Source
Center for International Forestry Research Mangrove Protocol	[50] Kauffman, J.B.; Donato, D.C. Protocols for the Measurement, Monitoring and Reporting of Structure, Biomass and Carbon Stocks in Mangrove Forests. 2012. Center for International Forestry Research.	https://www.cifor.org/publications/pdf_files/WPapers/WP86CIFOR.pdf
Mangrove carbon estimator and monitoring guide	[51] Food and Agriculture Organization of the United Nations, Mangrove Carbon Estimator and Monitoring Guide, 2016.	https://openknowledge.fao.org/server/api/core/bitstreams/2114792c-0a21-4bc9-a743-bb7bac296665/content

[50] J. B. Kauffman and D. C. Donato, "Protocols for the measurement, monitoring, and reporting of structure, biomass, and carbon stocks in mangrove forests." Center for International Forestry Research (CIFOR), 2012. https://www.cifor-icraf.org/knowledge/publication/3749/.

[51] Broadhead, J., J. Bukoski and N. Beresnev. 2016. Mangrove Carbon Estimator and Monitoring Guide. Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/2114792c-0a21-4bc9-a743-bb7bac296665/content.

APPENDIX 3| Guidelines for Biodiversity and Social Impacts Assessment

A3.1.1 | The activities shall demonstrate compliance with GS4GG requirements for SDGs contribution assessment. The project developers shall use the Gold Standard SDG tool to report the quantification and monitoring of SDGs contribution.

A3.1.2 | Appendix 3 provides guidelines to help project developers identify impacts (beyond SDG 13) of proposed activity following the multi-stakeholder participatory approach. The steps below are expected to be integrated with other project-related activities.

A3.1.3 | Below is a summary of the steps and corresponding recommended approach for identification and quantification of SDG contributions related to the social and biodiversity components.

Table A.38.1 Summary of steps, methods, and outputs for the social and biodiversity Sustainable Development Goal contribution

Steps	Description	Methods/Activities
1. Description of baseline condition and stakeholder identification	This stage illustrates the initial conditions (social and biodiversity) of the project area.	*Social:* Participatory rural appraisal, gender-sensitive community mapping, stakeholder analysis *Biodiversity:* Experts (both local and external), literature review, focus group discussion (FGDs), biodiversity field assessments
2. Baseline scenario (without project) social and biodiversity projections	This stage describes the projected social and biodiversity conditions of the area with the assumption that no project will be implemented. The drivers of mangrove deforestation are also identified here.	*Social:* FGDs, scenario development and analysis *Biodiversity:* Experts' (both local and external) evaluation
3. Project design and scenario	This stage describes how the project proponents are to achieve the social and biodiversity objectives through the project implementation.	Theories of change method (developed by the stakeholders)
4. Identification of negative impacts, risks, and prevention measures	Continuing with the use of the multi-stakeholder approach, this stage describes the potential negative social and biodiversity impacts of the project activities, their risks, and corresponding preventive measures.	*Social:* Analysis of FGDs, expert review *Biodiversity:* Experts' (both local and external) evaluation

Steps	Description	Methods/Activities
5. Identification of indicators	This stage provides the identified monitoring indicators to measure progress in achieving the social and biodiversity objectives.	*Social:* Indicators can be based on the analysis of FGDs, expert review *Biodiversity:* Indicators chosen by the experts' (both local and external) evaluation
6. Development of monitoring plan	This stage encompasses the design of a community-based monitoring plan to collect data and monitor the indicators.	*Social:* FGDs, participatory impact assessments, other data collection methods *Biodiversity:* Monitoring devised by experts' (both local and external) evaluation
7. Data collection, analysis, and reporting	This stage is composed of the data collection, analysis, and reporting of the indicators by the stakeholders.	Multi-stakeholder discussions, meetings, and feedback workshops

DOCUMENT HISTORY

Version	Date	Description
1.0	22.08.2024	First version