PV CLIMATE MODULE

PU##b

Simplified Mangrove restoration module

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Contents

1 Summary

This module provides simplified carbon accounting procedures for Plan Vivo Climate projects undertaking Mangrove Restoration or afforestation. It is part of PM00X, the modular Coastal Blue Carbon Methodology.

Mangrove Restoration and afforestation projects that fulfil the applicability conditions of this module can impact the climate in a number of ways. Firstly, the trees that grow because of the project can take CO_2 out of the atmosphere and store this as carbon in their wood, leaves and soil. These are called CO_2 removals and have a positive impact on the climate (*Carbon Benefit*), and thus can enable projects to generate PVCs. Projects can also lead to greenhouse gas (GHG) emissions, either through increased methane (CH_4) emissions due to flooding dry land with fresh water and/or CO_2 emissions from the soil or machinery as the land is prepared for Restoration. These emissions have a negative *Carbon Benefit* and thus decrease the number of PVCs a project can claim.

In some cases, Mangrove Restoration can also lead to emission reductions, for instance due to decreased CO_2 emissions from the soil due to the establishment of trees. These emission reductions are conservatively excluded from this module. Projects wishing to claim emission reductions due to Mangrove Restoration will be able to use the Alternative Mangrove Restoration module (PU##c), once it is available.

Mangrove Restoration and afforestation projects that fulfil the applicability conditions of both this module and PM00X can use the procedures detailed below to calculate the baseline, expected and actual CO_2 removals and GHG emissions due to *Project Interventions*. The results are then taken over to PM00X, which shows how to calculate a project's total *Carbon Benefit* and the number of PVCs that can be claimed, following adjustments for leakage, uncertainty and risk.

For each key step, worked examples are provided to walk projects through the application of the procedures, using a hypothetical mangrove Restoration project as an example.

The first step projects must take is defining the Target Area. This area represents the end vision for the *Project Area* (i.e. how the project participants intend the *Project Area* to look once the ecosystem is restored). The Target Area is used to understand how ecosystem structure is expected to vary across the *Project Area* once the Mangroves are restored. If ecosystem structure is expected to vary significantly, projects must Zone the *Project Area* and find representative Target Areas for each Zone.

The Carbon Baseline is established based on the ratio of the number of living woody Mangroves in the *Project Area* at the project start date compared to the matched Target Areas.

Expected CO_2 removals by woody vegetation are estimated using either default values or predicted biomass growth curves. Expected CO_2 removals in the soil organic carbon (SOC) pool are calculated using a default value. A full explanation of *Carbon Pools* and emission sources relevant in Mangrove ecosystems can be found in Section 5 of PM00X.

To estimate actual project CO_2 removals, there are two pathways. **Pathway One** uses default values for CO_2 removals in woody vegetation and SOC, and requires projects to monitor the number of living woody Mangroves in the *Project Area* and compare these numbers to the Target Areas to understand how the ecosystem is progressing towards a fully rehabilitated state. **Pathway Two** requires projects to monitor CO_2 removals in woody and non-woody vegetation, and apply a default value for CO_2 removals in the SOC pool.

Projects that dig channels to restore hydrology must use PT##a (Estimation of Emissions from the Soil Organic *Carbon Pool* due to Channel Digging in Mangroves) to estimate the associated emissions from the soil organic carbon pool. This module provides projects with procedures to account for all other GHG emissions.

Through the application of this module, projects will estimate values for the following parameters. Those used in PM00X are in **bold blue text** in this list and throughout the document.

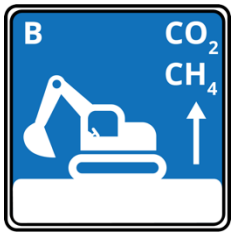
= **Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e)

= **Total baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e)

= **Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e). Due to the assumptions of this module, this parameter = 0

= **Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e). Due to the assumptions of this module, this parameter = 0

= **Total expected baseline emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e). Due to the applicability conditions and assumptions of this module, this parameter = 0



= **Total actual baseline emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e). Due to the applicability conditions and assumptions of this module, this parameter = 0

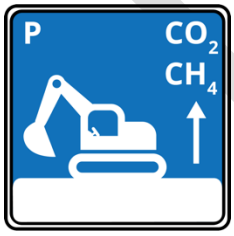
= **Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e)

= **Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e)

= **Total expected project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e)

= **Total actual project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e)

= **Total expected project emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period*** (tCO_2e)



= **Total actual project emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period*** (tCO_2e)

2 Sources

In addition to the modules and tools listed below, this module is designed to be applied in conjunction with PM00x for the estimation of carbon benefits from Mangrove Restoration.

This module includes procedures from the following Plan Vivo Climate and CDM Methodologies and Tools:

PT##a – Tool for calculating emissions due to channelling in mangrove ecosystems

PT##b – Uncertainty Calculator for Pathway One in PU##b

AR-AM0014 version 3.0 – Afforestation and reforestation of degraded Mangrove habitats

AR-TOOL03 version 2.1 – Calculation of the number of sample plots for measurements within A/R CDM project activities

AR-TOOL04 version 1.0 - Tool for testing significance of GHG emissions in A/R CDM project activities

AR-TOOL05 version 1.0 – Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities

AR-TOOL14 version 4.2 – Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities

This module also references the following guidance documents:

Coastal Blue Carbon; methods for assessing carbon stocks and emissions factors in Mangroves, tidal salt marshes, and seagrass meadows (Howard et al., 2014)[1]

Best Practice Guidelines for Mangrove Restoration (Beeston et al., 2023)[2]

Including Local Ecological Knowledge (LEK) in Mangrove Conservation & Restoration: A Best-Practice Guide for Practitioners and Researchers (Grimm et al., 2024)[3]

3 Definitions

Capitalised terms in this module are defined in the latest version of PM00X or below. Terms that are both Capitalised and *italicised* are defined in the Plan Vivo Climate Glossary.

Allochthonous Carbon – organic carbon that comes from outside of the *Project Area* and is deposited in the *Project Area*.

Dead Mangroves – Non-living mangroves of any height. Such mangroves may be dead saplings or dead trees, and can range in structure from dead trees with branches to tree stumps.

Mangrove Trees – Living woody Mangroves that are at least 1.5 m in height.

Mangrove Saplings – Living woody Mangroves that are less than 1.5 m in height.

[1] https://www.thebluecarboninitiative.org/manual
[2] https://www.Mangrovealliance.org/wp-content/uploads/2023/10/Best-Practice-for-Mangrove-Restoration-Guidelines-v2.pdf
[3] https://www.mangrovealliance.org/wp-content/uploads/2024/02/LEK-Guide-Master-Book_Final.pdf

Pre-Project Dead Mangroves – Dead Mangroves that are present in the *Project Area* at the project start date, prior to Restoration.

Pre-Project Mangrove Trees and Saplings – Mangrove Trees and Saplings that are present in the *Project Area* at the project start date, prior to Restoration.

Project Plot – A permanent monitoring plot, either 10 m x 10 m square or 7m in radius, located within the *Project Area* and used to establish the number of Pre-Project Mangrove Trees and Saplings at the *Project Start*, and monitor the number Mangrove Trees and Saplings during the *Crediting Period*.

Target Area – An area of Mangroves that represents the end vision of the project (i.e. it looks how the *Project Area* is intended to look once the vegetation is restored).

Target Plot – A monitoring plot, either 10 m x 10 m square or 7m in radius, located within the Target Area and used to establish the number of Mangrove Trees and Saplings that are expected to exist in the *Project Area* once Restoration is complete. Target Plots only need to be accessible to the project once, at the *Project Start*.

Woody Mangroves – A Mangrove tree or shrub that has a wood component to its structure. With the exception of *Nypa fruticans*, all of the dominant Mangrove species are woody (e.g. those of the genera *Avicennia, Lumnitzera, Bruguiera, Ceriops, Kandelia, Rhizophora* and *Sonneratia*).

Non-Woody Mangroves and Mangrove-Associate Species – Herbaceous vegetation that also has the capacity to grow in the intertidal Zone, including species such as *Acrostichum aureum* and *Nypa fruticans*.

4 Applicability Conditions

This module is applicable to Plan Vivo Climate projects that restore or afforest Mangrove ecosystems. This includes activities such as:

- Assisted natural regeneration (e.g. the community-based ecological Mangrove Restoration approach[4])
- Direct planting of Mangroves
- Building with Nature[5]
- Improved Mangrove management to enable Mangroves to grow back permanently in areas where they have been lost
- Development of alternative sources of non-Mangrove wood and/or income to enable Mangroves to grow back permanently in areas where they have been lost

All projects must fulfil the applicability conditions of the Coastal Blue Carbon methodology (PM00X). The following applicability conditions also apply to this module:

- Projects must be able to identify Target Area(s) which are representative of how the *Project Area* is intended to look once Restoration is complete, as outlined in Section 5.1.1, and access these areas for Mangrove counting prior to the start of the project.

[4] https://panorama.solutions/en/solution/community-based-ecological-Mangrove-restoration-cbemr
[5] https://panorama.solutions/en/solution/building-nature-safe-prosperous-and-adaptive-coastlines-indonesia

- Projects that involve channel digging in the *Project Area*, for instance to restore hydrology, must use the Tool to estimate emissions from the soil organic *Carbon Pool* due to channel digging in Mangroves (PT##a)
- Project activities do not include non-Mangrove wood use (e.g. to build sediment traps for Building with Nature initiatives) unless it can be demonstrated that the wood comes from a sustainable source.
- *Project Interventions* that clear non-woody vegetation (e.g. as part of site preparation) must use **Pathway Two** to estimate actual Carbon Benefit.
- *Project Interventions* do not include wood harvesting. *Project Interventions* that include partial (selective) harvesting will be allowed once the Sustainable Mangrove wood management module (PU##d) is developed.

This module can be used to claim fPVCs, rPVCs and vPVCs. There are no geographical or project size limitations to this module.

5 Procedures

This section describes the steps that projects need to follow to estimate their Carbon Benefit. At the end of each section there is a box that lists any required outputs that must be detailed in the *Project Design Document* (PDD).

The Plan Vivo Climate Project Requirements (section 1.2) state that projects can have more than one *Project Area*. In this module, the term '*Project Area*' covers all *Project Area*s. Thus, if a project has multiple *Project Area*s, this term should be interpreted as '*Project Area*s'.

This module is applicable to both Restoration and afforestation projects that meet the applicability conditions. For ease of reading, in the following sections the term 'Restoration' can be interpreted as encompassing both Restoration and afforestation.

5.1 Pre-Restoration activities

5.1.1 Understand the *Project Area* and define the Target Area

Mangroves are complex systems. The structure (e.g. the number and height of trees; the species present) of the system can vary across small and large areas. To use this module, projects need to understand and map how the structure of Mangroves, particularly the number of trees and Saplings, will vary across the *Project Area* once the vegetation is restored.

To do this, projects must identify a Target Area[6], which consists of Mangroves that reflect how the *Project Area* is intended to look once the vegetation is restored. They represent the end vision for the *Project Area*. The Target Area can be one contiguous area or formed of multiple different areas. All areas should be accessible to the project for Mangrove counting before the project start date (see Section 5.1.2) and be within 100 km of the *Project Area*, unless it can be demonstrated that no Mangroves exist within 100 km of the *Project Area*. If this is the case, the Target Areas must be within

[6] Target Areas are commonly used to assess the success of ecological restoration projects (SER, 2004; Wortley et al., 2013), and the term is used here to avoid confusion with 'Reference Area' often used in other methodologies.

the same marine ecoregion(s)[7] as the *Project Area*. If no Target Area can be found within the marine ecoregion(s), the project cannot use this module.

There is no minimum or maximum size for the Target Area, but the Target Area must cover the same range of elevations (which can be inferred from how often and for how long areas are inundated by the sea) as the *Project Area*.

Mangrove structure is affected by many things. Species dominance, which in turn is affected by tidal inundation (how often the area is flooded by the sea) and wave energy, is particularly important. Using information from the Target Area, in the PDD projects must:

- Describe the factors that influence Mangrove structure within the Target Area.
- Describe how these factors vary across the *Project Area*.

The outcome of this process is an understanding of how Mangrove structure, particularly number of trees and Saplings, varies across the Target Area and will vary across the *Project Area* once the vegetation has been restored. If the density/number of trees and Saplings varies significantly across the Target Area, the project should divide the area into Zones with similar numbers of trees and Saplings. These Zones should then be mapped onto the *Project Area*. This zoning process is called stratification. It is very important to carefully define the Zones because if the number of trees and Saplings vary too much within a Zone, the number of PVCs generated by the project may be reduced due to uncertainty (see Section 10.3 of PM00X). Tool PT##b together with results of the Mangrove counting process outlined in Section 5.1.2 can be used to understand whether the variability in a Zone is high or low.

Projects are strongly encouraged to incorporate local ecological knowledge into this process and can refer to Grimm et al., 2014 for guidance.

Figure 1 shows an example from a hypothetical project.

If the zoning of the *Project Area* needs to be revised any point in the *Crediting Period* – for instance if the original zoning is deemed to be inaccurate, or hydrological conditions change – clear justification must be provided in the PDD, explaining that the re-zoning leads to either more conservative or more accurate *Carbon Benefit* results.

Prior to Restoration, Mangrove Trees and Saplings may be present in the *Project Area*. These are called **Pre-Project Mangrove Trees and Saplings**. If the density of Pre-Project Mangrove Trees and Saplings varies significantly across a Zone, the project may wish to define further Zones according to the number of Pre-Project Mangrove Trees and Saplings (e.g. high density of Pre-Project Mangrove Trees and Saplings; low density of Pre-Project Mangrove Trees and Saplings). Tool PT##b together with the results of the Mangrove counting process outlined in Section 5.1.3 can be used to understand whether the variability in a Zone is high or low.

Required outputs from Section 5.1.1:

- Map(s) showing the Target Area and *Project Area*, and, if necessary, any Zones.

[7] As defined in Spalding et al., 2007 which can be accessed at https://www.arcgis.com/home/item.html?id=903c3ae05b264c00a3b5e58a4561b7e6

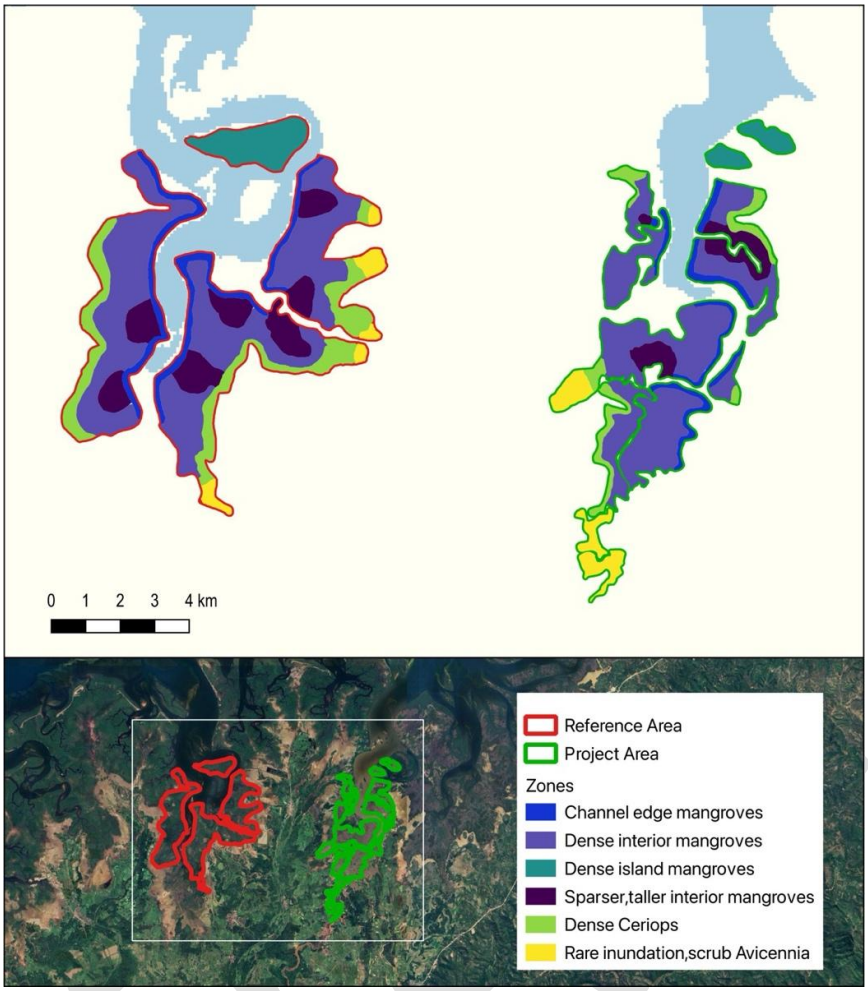


Figure 1 – An example of stratification of a hypothetical Project Area *and Target Area. The Target Area has been subdivided into Zones which contain similar numbers of trees and Saplings. By understanding how the factors that impact Mangrove structure vary across the* Project Area*, these Zones have been mapped onto the* Project Area*.*

5.1.2 Establish Target Plots and count living woody Mangroves

Plot locations should be established within the Target Area. These are called **Target Plots**. If the Target Area has been stratified, plots need to be established in each Zone. For Target Areas or Zones smaller than 200 hectares, at least one Target Plot per 20 hectares must be established and each Zone must have a minimum of 2 Target Plots. For Target Areas or Zones larger than 200 hectares, at least 10 Target Plots must be established. Plots must be randomly located within each Zone (i.e. random stratified sampling). See the worked example below for further explanation.

This module separates **living** woody Mangroves into two categories (Figure 2):

- **Mangrove Trees** are defined as living woody Mangroves that are **at least 1.5 m** in height
- **Mangrove Saplings** are defined as living woody Mangroves that are **smaller than 1.5 m** in height

Projects in arid environments, where Mangroves may not reach 1.5 m in height when they are fully mature, can justify a different definition of Mangrove tree. Such a revised definition must be used in all steps of this module.

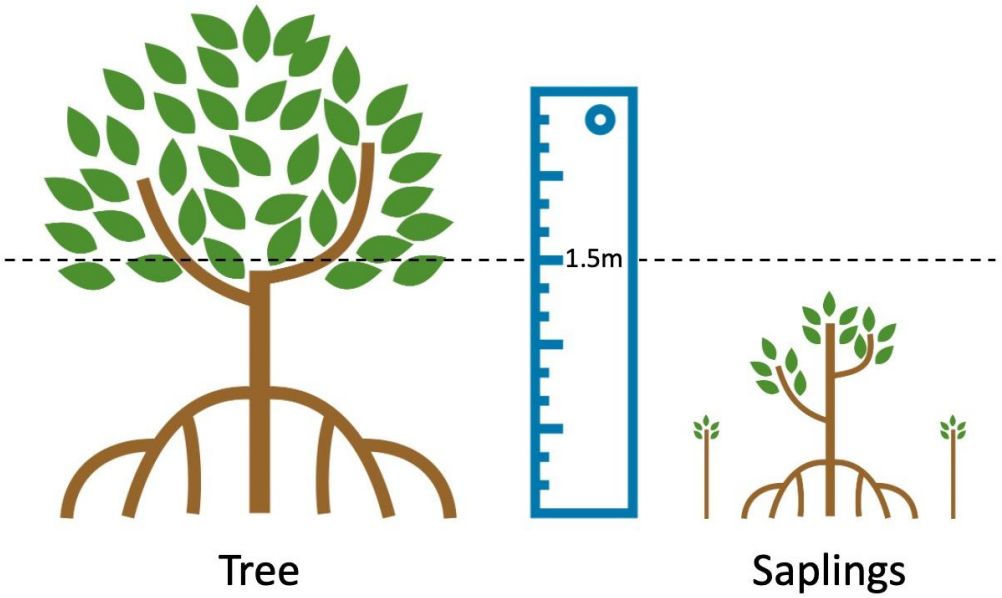


Figure 2 – Illustration to explain the distinction between Mangrove Trees and Mangrove Saplings used in this module. Mangrove Trees are living woody Mangroves that are at least 1.5 m in height. Mangrove Saplings are living woody Mangroves that are less than 1.5 m in height.

At each Target Plot location, all living Mangrove Trees and Saplings must be counted within 10 m x 10 m square plots or 7 m radius circular plots. The **average number of Mangrove Trees per Target Plot** and the **average number of Mangrove Saplings per Target Plot** must be calculated for **each Zone**. If the Target Area and *Project Area* have not been divided into Zones, the average number of Mangrove Trees per plot and the average number of Mangrove Saplings per plot within the Target Area must be calculated instead.

= Average number of Mangrove Trees in the Target Plots in each Zone in the Target Area

= Average number of Mangrove Saplings in the Target Plots in each Zone in the Target Area

The sum of the average number of Mangrove Trees and the average number of Mangrove Saplings must be calculated to give the **average number of living Mangroves per plot in each Zone**. See the worked example below for further explanation.

Equation 1:

= Average number of living Mangroves in the Target Plots in each Zone in the Target Area

If a project is unable to find a Target Area that it can access to measure Target Plots, peer-reviewed literature can be used to determine the average number of Mangrove Trees and Saplings in the Target Area. In this situation, clear evidence of lack of access to the Target Area must be presented in the PDD and the variance of any sampled data must be known, in order to estimate uncertainty (see Section 10.3 of PM00X).

Required outputs from Section 5.1.2:

- Map(s) showing the locations of the Target Plots within the Target Area

Average number of Mangrove Trees in the Target Plots in each Zone in the Target Area

Average number of Mangrove Saplings in the Target Plots in each Zone in the Target Area

Average number of living Mangroves in the Target Plots in each Zone of the Target Area

Worked example – Section 5.1.2

The size, in hectares, of the Zones in the hypothetical Target Area shown in Figure 1 are listed in the following table:

Zone name:	Area (ha)
Channel edge Mangroves	40
Dense *Ceriops*	70
Dense interior Mangroves	223
Dense island Mangroves	34
Rare inundation, scrub *Avicennia*	15
Sparser, taller interior Mangroves	72

Except for Zones larger than 200 ha, the number of Target Plots per Zone is calculated by dividing the area by 20. Thus, for the 'channel edge Mangroves' Zone, the number of plots = 40 ÷ 20 = 2 plots.

Each Zone must have at least 2 Target Plots, therefore, the 'Rare inundation, scrub Avicennia' Zone has 2 plots, even though 15 ÷ 20 is less than 2.

The 'Dense interior Mangroves' Zone is over 200 ha in size, therefore it has 10 Target Plots.

The number of Target Plots in each Zone is shown in the following table:

Zone name:	Area (ha)	Number of Target Plots:
Channel edge Mangroves	40	2
Dense *Ceriops*	70	4
Dense interior Mangroves	223	10
Dense island Mangroves	34	2
Rare inundation, scrub *Avicennia*	15	2
Sparser, taller interior Mangroves	72	4

These plots should then be randomly distributed within each Zone, as shown in Figure 3.

The table below shows the number of Mangrove Trees and Saplings in each Target Plot within the 'Channel edge Mangroves' Zone.

Plot number	Number of Mangrove Trees	Number of Mangrove Saplings
1	28	145
2	24	167

The average number of Mangrove Trees within the Target Plots is (28 + 24) ÷ 2 = **26**

The average number of Mangrove Saplings within the Target Plots is (145 + 167) ÷ 2 = **156**

The average number of living Mangroves within the Target Plots is 26 + 156 = **182**

Therefore, for the 'Channel edge Mangrove' Zone:

= 26

= 182

= 156

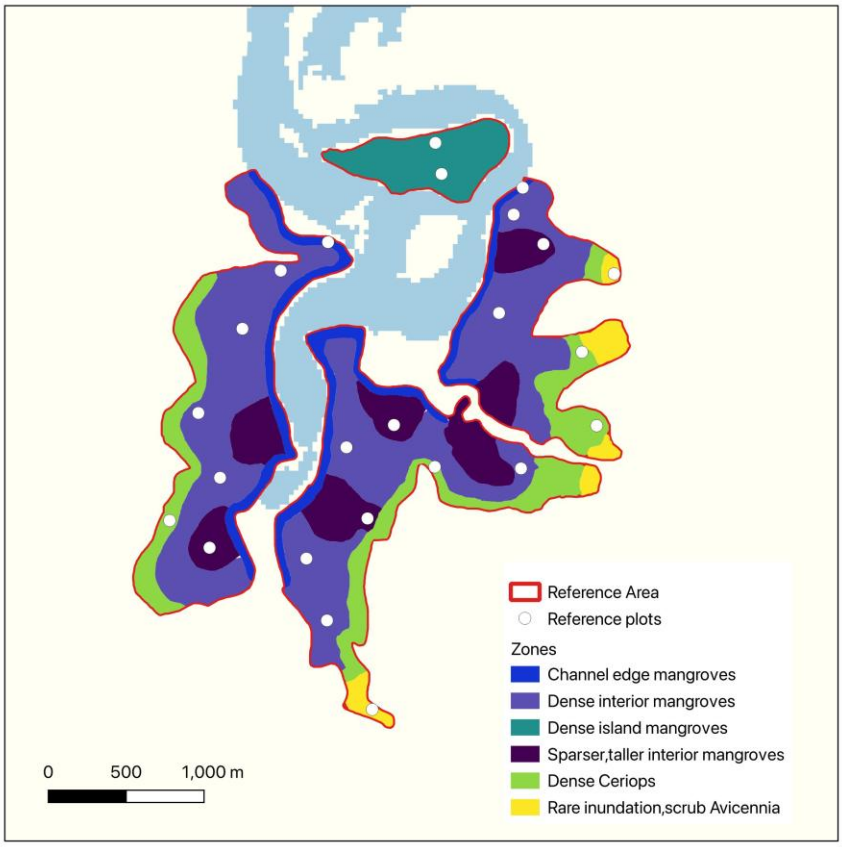


Figure 3 – The required number of Target Plots distributed randomly within each Zone of the Target Area.

5.1.3 Establish Project Plots and count woody Mangroves

Permanent plot locations must be established within the *Project Area*. These are called **Project Plots**.

If the *Project Area* has been stratified, plots need to be established in each Zone. For a *Project Area* or Zone smaller than 200 hectares, at least one Project Plot per 2 hectares must be established and each Zone must have a minimum of 10 Project Plots. For *Project Area*s or Zones larger than 200 hectares, at least 100 Project Plots must be established. Plots must be randomly located within each Zone (i.e. random stratified sampling). See the worked example below for further explanation.

Prior to Restoration, Mangrove Trees and Saplings may be present in the *Project Area*. These are called **Pre-Project Mangrove Trees and Saplings**, and they need to be counted[8].

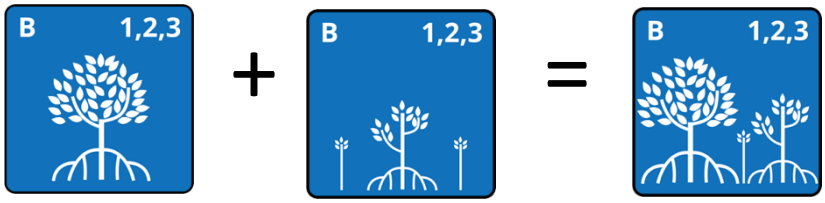
At each Project Plot location, all living Pre-Project Mangrove Trees and Saplings must be counted within 10 m x 10 m square plots or 7 m radius circular plots. The same plot design (square or circular) must be used for both the Target Plots and Project Plots. The **average number of Pre-Project Mangrove Trees per Project Plot** and the **average number of Pre-Project Mangrove Saplings per Project Plot** must be calculated for **each Zone**. If the *Project Area* has not been divided into Zones, the average number of Pre-Project Mangrove Trees per Project Plot and the average number of Pre-Project Mangrove Saplings per Project Plot within the *Project Area* must be calculated instead.

= Average number of Pre-Project Mangrove Trees in the Project Plots in each Zone in the *Project Area*

= Average number of Pre-Project Mangrove Saplings in the Project Plots in each Zone in the *Project Area*

The sum of the average number of Pre-Project Mangrove Trees and the average number of baseline Pre-Project Saplings must be calculated to give the **average number of Pre-Project living Mangroves per plot in each Zone**.

Equation 2:

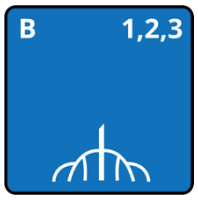


[8] For existing PVC projects migrating from previous versions to version 5 of the Standard must estimate the number of baseline mangrove trees and saplings that were in the Project Plots prior to restoration. This can be done using field data, remote sensing data, peer-reviewed or grey literature, historical photographs and/or local ecological knowledge. Evidence must be provided in the PDD that demonstrates that the estimated values are conservative (larger values are more conservative).

Where:

= Average number of Pre-Project living Mangroves in the Project Plots in each Zone in the *Project Area*

Projects following Pathway One to calculate actual project removals must also count all Pre-Project Dead Mangroves within each Project Plot. The **average number of Pre-Project Dead Mangrove per Project Plot** must be calculated for **each Zone**. If the *Project Area* has not been divided into Zones, the average number of Dead Mangrove per Project Plot within the *Project Area* must be calculated instead.



= Average number of Pre-Project Dead Mangroves in the Project Plots in each Zone in the *Project Area*

Projects following Pathway One to calculate actual project removals or any project wishing to claim rPVCs must also take geolocated photographs[9] at the centre of each Project Plot. At a minimum, one photo must be taken facing in each cardinal direction (i.e. north, east, south and west). All photos should be uploaded and organised in an online file sharing platform[10].

Required outputs from Section 5.1.3:

- Map(s) showing the locations of the Project Plots within the *Project Area*
- ***For Pathway One projects or any project wishing to claim rPVCs***: Geolocated photographs taken at the centre of each Project Plot, facing in each cardinal direction (i.e. north, east, south, west), and uploaded to an online file sharing platform.

Average number of Pre-Project Mangrove Trees in the Project Plots in each Zone in the *Project Area*

Average number of Pre-Project Mangrove Saplings in the Project Plots in each Zone in the *Project Area*

[9] There are many mobile applications that enable users to take GPS-stamped photographs. Examples include 'Conota – Timestamp GPS Camera' and 'Timemark:Photo Proof'. However, projects are not required to use such applications.
[10] Such as Google Drive or Dropbox.

Required outputs from Section 5.1.3:

Average number of Pre-Project living Mangroves in the Project Plots in each Zone in the *Project Area*

Average number of Pre-Project Dead Mangroves in the Project Plots in each Zone in the *Project Area*

Worked example – Section 5.1.3

The size, in hectares, of the Zones in the hypothetical *Project Area* shown in Figure 1 are listed in the following table:

Zone name:	Area (ha)
Channel edge Mangroves	26
Dense *Ceriops*	25
Dense interior Mangroves	174
Dense island Mangroves	15
Rare inundation, scrub *Avicennia*	25
Sparser, taller interior Mangroves	28

Except for Zones larger than 200 ha, the number of Project Plots per Zone is calculated by dividing the area by 2. Thus, for the 'channel edge Mangroves' Zone, the number of plots = 26 ÷ 2 = 13 plots.

Each Zone must have at least 10 Project Plots, therefore, the 'Dense island Mangroves' Zone has 10 plots, even though 15 ÷ 2 is less than 10.

No Zone is larger than 200 ha. But if it were, it would have 100 Project Plots.

The number of Target Plots in each Zone is shown in the following table:

Zone name:	Area (ha)	Number of Project Plots:
Channel edge Mangroves	26	13
Dense *Ceriops*	25	13
Dense interior Mangroves	174	87
Dense island Mangroves	15	10
Rare inundation, scrub *Avicennia*	24	12
Sparser, taller interior Mangroves	28	14

These plots should then be randomly distributed within each Zone, as shown in Figure 4.

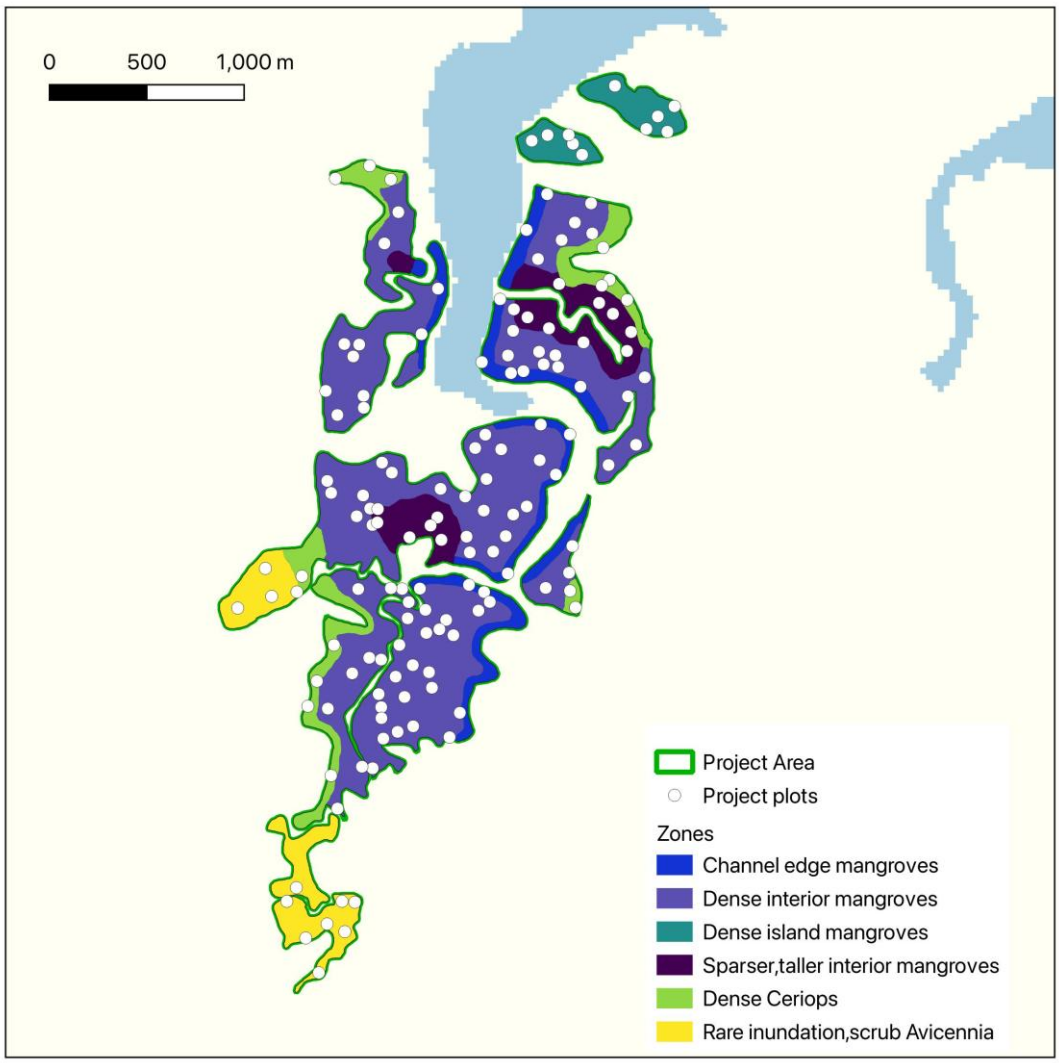


Figure 4 - The required number of Project Plots distributed randomly within each Zone of the Project Area.

5.2 Carbon Baseline

5.2.1 Further describe the baseline scenario

Projects identify and justify the baseline scenario for the project (e.g. continuation of Pre-Project land use) by applying the procedures in Section 6.2 of PM00X. To use this module, projects need to further describe what is expected to happen to Mangroves in the *Project Area* in the absence of the *Project Interventions*.

Through participatory social research and/or remote sensing analyses, detailed in the *PDD* and supported with evidence where possible, the project must identify and justify which of the following three baseline Mangrove vegetation scenarios is relevant to the *Project Area* (Figure 5):

Baseline Mangrove vegetation scenario 1: The area remains under threat and any remaining Mangrove vegetation will likely be lost.

Baseline Mangrove vegetation scenario 2: The area remains under threat but in a steady state. Or, threats have ceased but there are demonstrated barriers to natural regeneration. Or, in the case of afforestation, Mangroves are not expected to grow in the *Project Area* in the next 10 years. Thus, Mangrove vegetation levels are not expected to change significantly in the baseline scenario.

Baseline Mangrove vegetation scenario 3: Some of the threats that historically caused Mangrove loss have ceased or are no longer relevant, and the Mangrove vegetation has the capacity to partially naturally regenerate. Projects that cannot demonstrate barriers to natural regeneration must select this scenario.

If one single scenario cannot be applied to the whole *Project Area*, the *Project Area* must be zoned according to baseline Mangrove vegetation scenario, in addition to any Zones identified in Section 5.1.1.

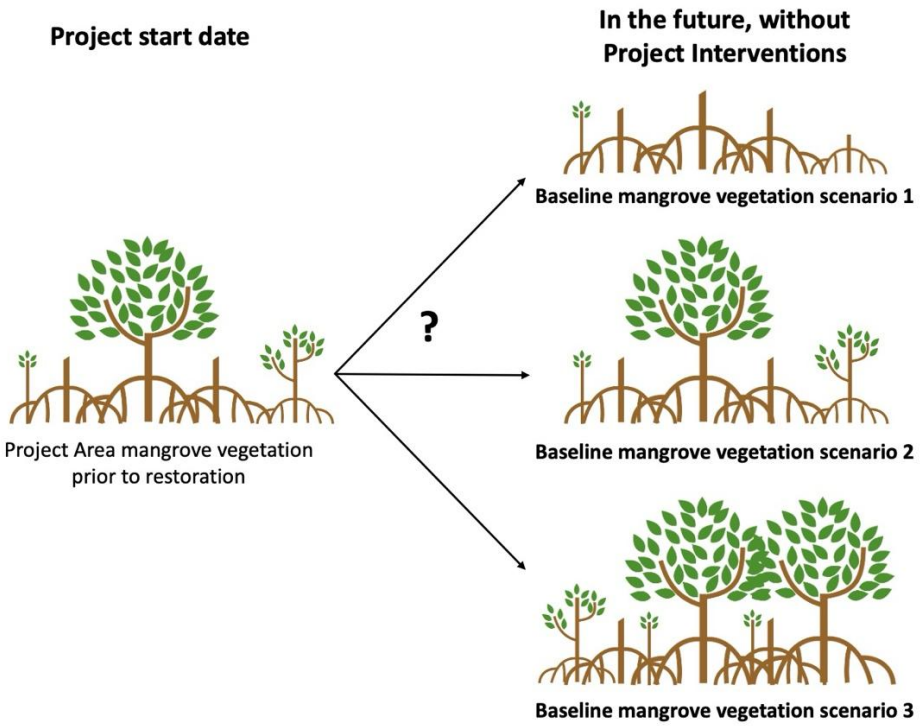


Figure 5 – Illustration of the three baseline Mangrove vegetation scenarios.

Required outputs from Section 5.2.1:

- Justification of the choice of baseline Mangrove vegetation scenario(s).
- If more than one scenario is applicable to the *Project Area*, a map outlining the baseline Mangrove vegetation scenario Zones.

5.2.2 Calculate the baseline adjustment

This module estimates baseline CO_2 removals by applying an adjustment factor to expected and actual project CO_2 removals. This adjustment is calculated by comparing the number of Mangroves within the *Project Area* prior to Restoration to the number of Mangroves within the Target Area.

The size of the adjustment depends on the baseline Mangrove vegetation scenario defined in Section 5.2.1. It is calculated as follows (see also the worked example below):

For *Project Area* Zones with baseline Mangrove vegetation scenario 1 or 2

Equation 3:

Where:

= Baseline adjustment

For *Project Area* Zones with baseline Mangrove vegetation scenario 3

Equation 4:

Required outputs from Section 5.2.2:

Baseline adjustments for all Zones of the *Project Area* (unitless)

Worked example – Section 5.2.2

The following table shows the relevant Target Area and baseline vegetation parameters for the 'Channel edge Mangrove' Zone of the hypothetical *Project Area* shown in Figure 1:

Channel edge mangroves	
Parameter	Value
 Average number of mangrove trees in the reference plots	26
 Average number of living mangroves in the reference plots	156
 Average number of baseline mangrove trees in the project plots	3
 Average number of baseline living mangroves in the project plots	62

Social research indicated that the baseline Mangrove vegetation scenario for this Zone is **scenario 2**. Therefore, the baseline adjustment is calculated as follows:

3 ÷ 26 = **0.12**

However, if the baseline vegetation scenario was **scenario 3** then the baseline adjustment would be calculated as follows:

62 ÷ 156 = **0.4**

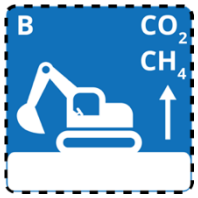
5.2.3 Baseline emissions and removals

This module estimates baseline CO_2 removals by applying the baseline adjustment to expected and actual project CO_2 removals. Therefore, the equations used to calculate baseline removals are in Sections 5.3.3 and 5.6.5 below.

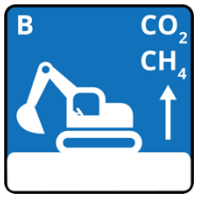
Any GHG emissions that would occur in the baseline scenario, in the absence of the *Project Intervention*, are conservatively excluded from this module. Therefore:

$= 0$

= 0



= 0

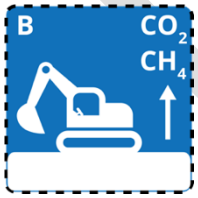


= 0

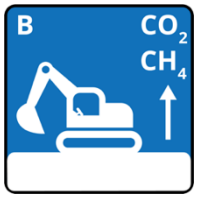
Where:

= Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

= Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*



= Total expected baseline emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*



= Total actual baseline emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

5.2.4 Baseline reassessment

The baseline needs to be reassessed at least every 10 years during the *Crediting Period*. To do this, through participatory social research and/or remote sensing analyses (for instance, remote sensing analyses of biomass growth in degraded areas outside of the *Project Area*) the project must reassess and justify which of the three baseline Mangrove vegetation scenarios is most relevant to the *Project Area*. This process and the justification of the baseline Mangrove vegetation scenario(s) chosen must be detailed in the PDD.

If the baseline Mangrove vegetation scenario changes, the baseline adjustment must be recalculated using the Equation 3 or 4, as applicable. This revised baseline adjustment must be used until the next baseline reassessment.

If the baseline Mangrove vegetation scenario changes and more than one scenario applies to the project, the *Project Area* Zones related to the baseline Mangrove vegetation scenario also need to be reassessed and, if necessary, revised.

Required outputs from Section 5.2.4:

At least every 10 years during the *Crediting Period*:

- Reassessment of the baseline Mangrove vegetation scenario through participatory social research and/or remote sensing analyses. This process and the justification of the baseline Mangrove vegetation scenario(s) chosen must be detailed in the PDD.
- If the baseline Mangrove vegetation scenario changes, revised value for the following parameter:

B %

Baseline adjustments for all Zones of the *Project Area* (unitless)

- If more than one baseline Mangrove vegetation scenario applies to the project, maps of the *Project Area* showing any revised zoning.

5.3 Expected baseline and project removals

All projects must provide estimates for baseline and project emissions and removals for all years of the *Crediting Period*. This section explains how projects do this.

5.3.1 Estimate the expected *Project Intervention* schedule

Projects must summarise in a table the total area, in hectares, within each Zone that is expected to be undergoing Restoration in each year of the *Crediting Period*. See the worked example below. For projects that plant Mangroves, this is the cumulative hectares of Mangroves planted in each Zone in each year of the project.

= Total area in each Zone that is expected to be undergoing Restoration in each year of the *Crediting Period* (ha)

Required outputs from Section 5.3.1:

Total area in each Zone that is expected to be undergoing Restoration in each year of the *Crediting Period* (ha).

Worked example – Section 5.3.1

The 'Channel edge Mangroves' Zone in the hypothetical *Project Area* shown in Figure 1 is 26 ha in size. The table below details the expected Restoration schedule for this Zone and the total areas expected to be undergoing Restoration in each year of a 20-year *Crediting Period*:

Channel edge mangroves		
Year	New area expected to be undergoing restoration (ha)	Total area expected to be undergoing restoration (ha)
1	4	4
2	5	9
3	5	14
4	7	21
5	5	26
6	0	26
7	0	26
8	0	26
9	0	26
10	0	26
11	0	26
12	0	26
13	0	26
14	0	26
15	0	26
16	0	26
17	0	26
18	0	26
19	0	26
20	0	26

5.3.2 Calculate expected project CO_2 removals

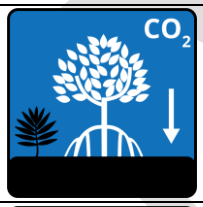
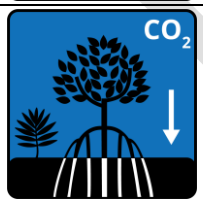
Projects following PATHWAY ONE to calculate actual project removals:

Projects following Pathway One to calculate actual project removals must use default values for annual CO_2 removals in all applicable *Carbon Pools*. The default values for aboveground woody biomass and belowground biomass are based on the Tier 1 values in the Wetlands supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[11], with an adjustment factor to ensure the values are conservative in all situations[12]. For soil organic carbon, a conservative value derived from literature and incorporating a deduction for allochthonous[13] carbon is used[14]. The full justification for the default values can be found in Annex One.

Projects must first determine whether the *Project Area* is in the Tropical Wet or Tropical Dry IPCC climate Zone[15]. If the *Project Area* covers multiple IPCC climate Zones, the *Project Area* must be stratified according to climate Zone and the relevant default values applied to each Zone.

CO_2 removals per hectare per year in each *Carbon Pool* for each IPCC climate Zone are summarised in Tables 1 and 2.

Table 1 – Annual CO_2 removals for each Carbon Pool that can be claimed by projects in the Tropical Wet IPCC climate Zone. As well as the time limits applied to each Carbon Pool.

Tropical Wet IPCC climate Zone			
Parameter	**Description**	**Value**	**Time limit**
	Annual per hectare CO_2 removals in aboveground woody biomass.	**10.6** tCO_2e/ha/year	Can only be applied for **30 years** from the start of Restoration.
	Annual per hectare CO_2 removals in belowground biomass.	**5.2** tCO_2e/ha/year	

[11] 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/

[12] 65% of the IPCC Tier 1 values for biomass growth rates are used in this methodology, together with the carbon stock values of mature Mangroves, which in this module reflect the maximum carbon stock that can accumulate in Mangroves.

[13] Allochthonous carbon is organic carbon that originates from outside of the Project Area and not from the Mangroves that the project is restoring, but is deposited in the *Project Area* during the *Crediting Period*.

[14] This default factor was derived from the average soil carbon burial rate published in Alongi and Zimmerman, 2024, minus the 90% confidence interval https://www.int-res.com/abstracts/meps/v733/meps14560. A 51% deduction was applied for allochthonous carbon, which is the average contribution of non-mangrove derived organic carbon in estuarine systems presented in Zang et al., 2024 https://www.nature.com/articles/s41467-024-53413-z

[15] This tool can be used to establish which IPCC climate Zone(s) the project is in: https://planvivo.shinyapps.io/bluecarbontool/

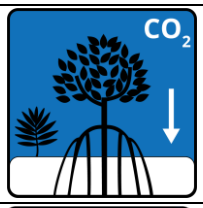
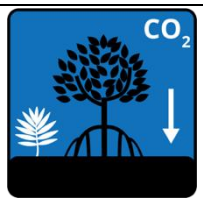
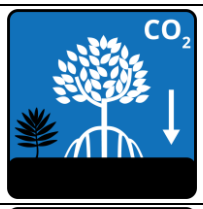
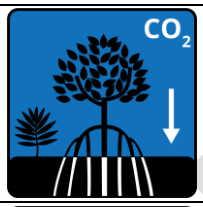
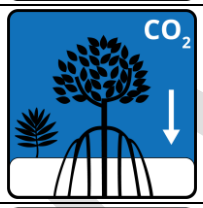
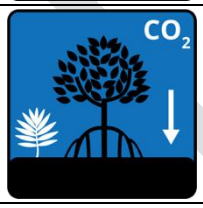
	Annual per hectare CO_2 removals in the soil organic *Carbon Pool*.	**4.0** tCO_2e/ha/year	No time limit. Can be applied in all years of the *Crediting Period* after the start of Restoration.
	Annual per hectare CO_2 removals in aboveground non-woody biomass.	**0** tCO_2e/ha/year	CO_2 removals in the non-woody biomass pool are conservatively excluded.

Table 2 – Annual CO_2 removals for each Carbon Pool that can be claimed by projects in the Tropical Dry IPCC climate Zone. As well as the time limits applied to each Carbon Pool.

Tropical Dry IPCC climate Zone			
Parameter	**Description**	**Value**	**Time limit**
	Annual per hectare CO_2 removals in aboveground woody biomass.	**3.7** tCO_2e/ha/year	Can only be applied for **41 years** from the start of Restoration.
	Annual per hectare CO_2 removals in belowground biomass.	**1.1** tCO_2e/ha/year	
	Annual per hectare CO_2 removals in the soil organic *Carbon Pool*.	**4.0** tCO_2e/ha/year	No time limit. Can be applied in all years of the *Crediting Period* after the start of Restoration.
	Annual per hectare CO_2 removals in aboveground non-woody biomass.	**0** tCO_2e/ha/year	CO_2 removals in the non-woody biomass pool are conservatively excluded.

For each Zone in the *Project Area* in each year of the *Crediting Period*, expected CO_2 removals in each *Carbon Pool*, **within the time limits** explained in Tables 1 and 2, are calculated as follows:

Equation 5:

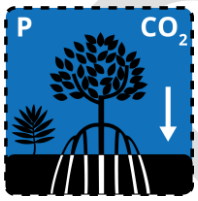
Equation 6:

Equation 7:

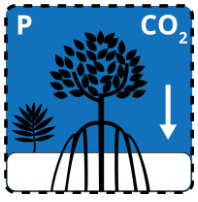
Equation 8:

Where:

= Expected project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*



= Expected project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

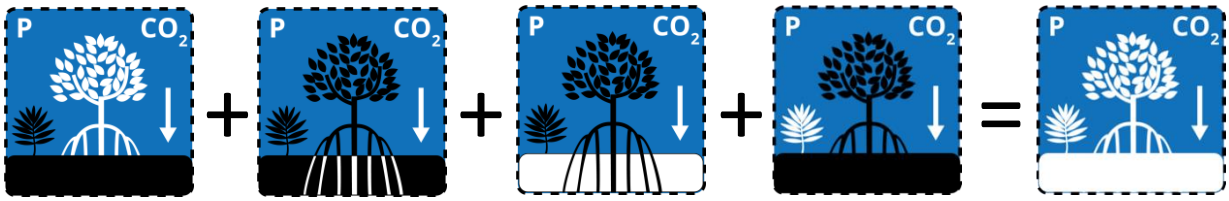


= Expected project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

= Expected project CO_2 removals in the aboveground non-woody biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* are calculated as follows:

Equation 9:



Where:

= **Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period***

See the worked example below.

Projects following PATHWAY TWO to calculate actual project removals:

Projects following Pathway Two must also use Equations 5-9.

To estimate expected CO_2 removals per hectare in the aboveground woody and the belowground biomass *Carbon Pools*, projects following Pathway Two can:

- use the default values in Tables 1 and 2, depending on the IPCC climate Zone(s) the *Project Area* is within, and equations 5-9
  or
- Modelling of tree growth and stand development, following the procedures in AR-TOOL14 version 4.2 Section 8.2.

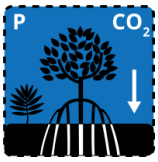
At the end of each *Verification Period*, projects wishing to claim rPVCs during consequent *Reporting Periods* must demonstrate the continued applicability of the values used for expected CO_2 removals per hectare in the aboveground woody and the belowground biomass *Carbon Pools* by comparing them to the results of the monitoring outlined in Section 5.6.4.

For expected CO_2 removals per hectare in the aboveground non-woody biomass and soil organic *Carbon Pools*, the values in Table 1 must be used.

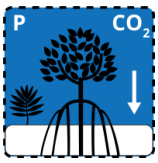
Required outputs from Section 5.3.2:

- If following Pathway One or using the IPCC default values in Tables 1 and 2, justification of the IPCC climate Zone(s) the *Project Area* is within.

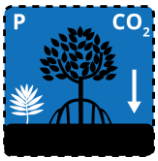
Expected project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)



Expected project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)



Expected project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)



Expected project CO_2 removals in the aboveground non-woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Worked example – Section 5.3.2

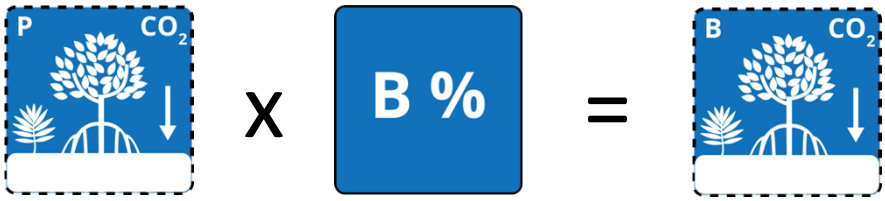
The following table explains how expected project CO_2 removals for each *Carbon Pool* and the total expected project CO_2 removals are calculated for each year of a 20-year *Crediting Period*, using the 'Channel edge Mangroves' Zone from the hypothetical *Project Area* as an example. The *Project Area* is in the Tropical Wet IPCC climate Zone, so the numbers in Table 1 are multiplied by the total area expected to be under Restoration in each year. The annual CO_2 removal values for the aboveground woody biomass and belowground biomass pools can only be applied for 30 years from the start of Restoration. But the *Crediting Period* is less than 30 years, so this restriction does not apply.

Channel edge mangroves							
Year	New area expected to be undergoing restoration (ha)	ha (ha)	P CO2 (tCO_2e/year)	P CO2 (tCO_2e/year)	P CO2 (tCO_2e/year)	P CO2 (tCO_2e/year)	P CO (tCO_2e/year)
1	4	4	10.6 x 4 = 42	5.2 x 4 = 21	4.0 x 4 = 16	0 x 4 = 0	42 + 21 + 16 + 0 = 79
2	5	9	10.6 x 9 = 95	5.2 x 9 = 47	4.0 x 9 = 36	0 x 9 = 0	95 + 47 + 36 + 0 = 178
3	5	14	10.6 x 14 = 148	5.2 x 14 = 73	4.0 x 14 = 56	0 x 14 = 0	148 + 73 + 56 + 0 = 277
4	7	21	10.6 x 21 = 223	5.2 x 21 = 109	4.0 x 21 = 84	0 x 21 = 0	223 + 109 + 82 + 0 = 414
5	5	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
6	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
7	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
8	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
9	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
10	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
11	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
12	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
13	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
14	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
15	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
16	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
17	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
18	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
19	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516
20	0	26	10.6 x 26 = 277	5.2 x 26 = 135	4.0 x 26 = 104	0 x 26 = 0	277 + 135 + 104 + 0 = 516

5.3.3 Calculate expected baseline CO_2 removals

For each Zone in the *Project Area* in each year of the *Crediting Period*, expected baseline CO_2 removals in all *Carbon Pools* are calculated by multiplying the expected project removals by the baseline adjustment:

Equation 10:



Where:

= **Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period***

See the worked example below.

Required outputs from Section 5.3.3:

Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Worked example – Section 5.3.3

The following table explains how the total expected baseline CO_2 removals are calculated for each year, using the 'Channel edge Mangroves' Zone from the hypothetical *Project Area* as an example, whose baseline adjustment was calculated to be 0.12.

Channel edge mangroves			
Year	 (tCO_2e/year)	 Unitless	 (tCO_2e/year)
1	79	0.12	79 x 0.12 = 9
2	178	0.12	178 x 0.12 = 21
3	277	0.12	277 x 0.12 = 33
4	414	0.12	414 x 0.12 = 50
5	516	0.12	516 x 0.12 = 62
6	516	0.12	516 x 0.12 = 62
7	516	0.12	516 x 0.12 = 62
8	516	0.12	516 x 0.12 = 62
9	516	0.12	516 x 0.12 = 62
10	516	0.12	516 x 0.12 = 62
11	516	0.12	516 x 0.12 = 62
12	516	0.12	516 x 0.12 = 62
13	516	0.12	516 x 0.12 = 62
14	516	0.12	516 x 0.12 = 62
15	516	0.12	516 x 0.12 = 62
16	516	0.12	516 x 0.12 = 62
17	516	0.12	516 x 0.12 = 62
18	516	0.12	516 x 0.12 = 62
19	516	0.12	516 x 0.12 = 62
20	516	0.12	516 x 0.12 = 62

5.4 Expected project emissions

Projects fulfilling the applicability conditions of PM00X and this module may produce emissions from the following *Carbon Pools* and emission sources:

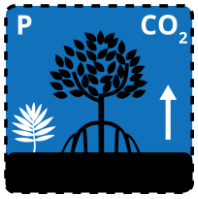
- Aboveground non-woody biomass
- Soil organic carbon
- Soil methanogenesis (methane (CH_4) emissions from the soil)
- CO_2 emissions from fossil fuel use

Projects can avoid accounting for one or more of the above emissions if they can demonstrate that the total excluded emissions are insignificant using AR-TOOL04 version 1.0.

5.4.1 Calculate expected project CO_2 emissions from the aboveground non-woody biomass *Carbon Pool*

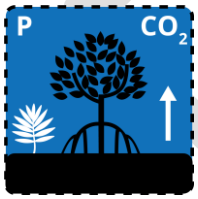
Only projects following Pathway Two and whose *Project Interventions* include the clearing of aboveground non-woody biomass are required to estimate emissions from this *Carbon Pool* in the project scenario.

For all other projects:



$= 0$

Where:



= Expected project CO_2 emissions in the aboveground non-woody biomass *Carbon Pool* in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

Expected emissions from aboveground non-woody biomass can be estimated using either peer-reviewed published literature or field measurements. Guidance on how to measure carbon stocks in non-woody biomass can be found in the Howard et al., 2014[16].

5.4.2 Calculate expected project CO_2 emissions from the soil organic carbon *Carbon Pool*

Only projects whose *Project Interventions* include the digging of channels (e.g. to restore hydrology) are required to account for emissions from the soil organic carbon pool.

[16] https://www.thebluecarboninitiative.org/manual

For all other projects:

= 0

Where:

= Expected project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

Projects that dig channels must use PT##a (Estimation of Emissions from the Soil Organic *Carbon Pool* due to Channel Digging in Mangroves) to estimate this parameter.

5.4.3 Calculate expected project methane (CH_4) emissions

Only projects whose *Project Interventions* include the flooding of dry land where the salinity low point[17] is below 18 ppt are required to account for soil methanogenesis in the project scenario.

For all other projects:

= 0

Where:

= Expected project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

[17] The salinity low point should be measured on shallow pore water (within 30 cm from soil surface) using a handheld salinity refractometer or other accepted technology. The salinity low point must be calculated from observations that represent variation in salinity during periods of peak CH_4 emissions (e.g., during the growing season in temperate ecosystems or the wet season in tropical ecosystems).

For each Zone of the *Project Area*, CH_4 emissions from soils may be estimated using either of the following:

- Peer-reviewed published data
- Emission factors from the Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[18]

Peer-reviewed published data must be limited to systems that are in the same or similar region as the *Project Area*, share similar geomorphic, hydrologic, and biological properties, and are under similar management regimes unless any differences should not have a substantial effect on methane emissions.

To convert methane emissions to tCO_2e, the most recent 100-year IPCC Global Warming Potential must be used. The AR6 2021 Global Warming Potential for methane is 27.2[19].

5.4.4 Calculate expected CO_2 emissions from fuel use

Only projects that involve the movement of soil with machinery (e.g. through the Restoration of hydrology in aquaculture ponds) are required to account for fossil fuel use in the project scenario.

For all other projects:

= 0

Where:

= Expected annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* (tCO2e) in each year of the *Crediting Period* (parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0)

AR-TOOL05 version 1.0 must be used to estimate CO_2 emissions due to fossil fuels.

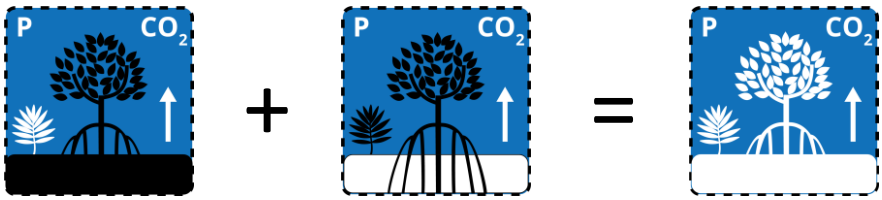
5.4.5 Estimate total expected project emissions

The aboveground non-woody biomass and soil organic carbon pools are the only potential sources of emissions from *Carbon Pools* for projects fulfilling the applicability conditions of PM00X and this module. Therefore, the total expected project emissions from *Carbon Pools* are calculated as follows:

[18] 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/

[19] https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf

Equation 11:

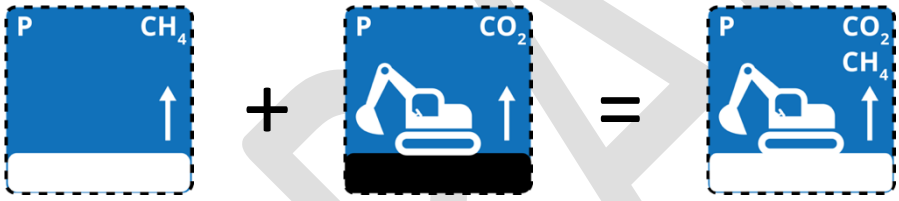


Where:

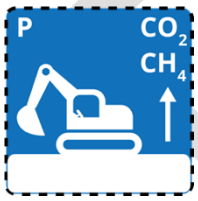
= **Total expected project emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period***

Total expected project emissions from emissions sources are calculated as follows:

Equation 12:



Where:



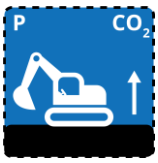
= **Total expected project emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period***

Required outputs from Section 5.4:

Expected project CO_2 emissions in the aboveground non-woody biomass *Carbon Pool* in each relevant Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

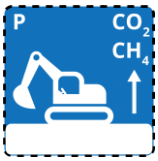
Expected project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Expected project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)



Expected annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* in each year of the *Crediting Period* (parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0) (tCO_2e)

Total expected project emissions in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period* (tCO_2e)



Total expected project emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period* (tCO_2e)

5.5 Calculate total expected removals and emissions across all Zones

The final step is to calculate the total expected removals and emissions in the baseline and project scenarios across **all Zones** for **each year of the *Crediting Period***. This is done by summing the values in all Zones for the following parameters:

= Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

= **Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period*.** The applicability conditions and assumptions of this module mean this parameter = 0.

= **Total expected baseline emissions from all emission sources across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period.*** The applicability conditions and assumptions of this module mean this parameter = 0.

= **Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period.***

= **Total expected project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period.***

= **Total expected project emissions from all emission sources across all Zones of the *Project Area* (tCO_2e) for each year of the *Crediting Period.***

These parameters are then used in PM00X to estimate the expected *Carbon Benefit* of the project.

For each year of the *Crediting Period*, these values must be presented in the PDD in table format[20].

Required outputs from Section 5.5:

Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

[20] This spreadsheet shows an example table that is suitable for the PDD (see the 'Expected' sheet), using the hypothetical *Project Area* referenced throughout the worked examples in this module. The equations are for explanation, in line with the other worked examples, and do not need to be visible in the table in the PDD: https://docs.google.com/spreadsheets/d/1F3Vg1WYde7PX_KgBQZIDCDHY7IArH0VDWRVDLlCEZyE/edit?usp=sharing

Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Total expected baseline emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Total expected project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

Total expected project emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period* (tCO_2e)

5.6 Actual baseline and project removals

To estimate actual project CO_2 removals, the Mangroves in the *Project Area* are counted (Pathway One) or measured (Pathway Two). This is a key part of the *Verification* process and is required for the issuance of vPVCs. The time between the current Mangrove counting/measurement campaign and the last Mangrove counting/measurement campaign is called the *Verification Period*.

5.6.1 Map and measure the Restoration areas

Projects must map and summarise in a table the total area, in hectares, within each Zone that is undergoing Restoration in each year of the *Crediting Period*. See worked example below. For projects that plant Mangroves, this is the cumulative hectares of Mangroves planted in each Zone in each year of the project.

= Total area in each Zone that is undergoing Restoration in each year of the *Verification Period* (ha)

Required outputs from Section 5.6.1:

- Map and GIS files (e.g. .kml or .shp files) showing areas undergoing Restoration in each Zone of the *Project Area* in each year of the *Verification Period*

Total area in each Zone that is undergoing Restoration in each year of the *Verification Period* (ha).

Worked example – Section 5.6.1

The 'Channel edge Mangroves' Zone in the hypothetical *Project Area* shown in Figure 1 is 26 ha in size.

The project conducts its first tree counting campaign at the end of Year 3. Therefore, the first *Verification Period* is Years 1-3.

The table below details the areas beginning Restoration in this Zone and the total areas undergoing Restoration during the *Verification Period*:

Channel edge mangroves		
Year	New area undergoing restoration (ha)	Total area undergoing restoration (ha)
1	4	4
2	6	10
3	5	15

5.6.2 Take photos within the Project Plots

This step is only required for projects following Pathway One to calculate actual project removals or any projects wishing to claim rPVCs. Projects following Pathway Two that do not want to claim rPVCs can skip this step.

Geolocated photographs[21] must be taken at the centre of each Project Plot that is within an area undergoing Restoration. This is called Photo Monitoring and must be done every time Mangroves are counted. At a minimum, one photo must be taken facing in each cardinal direction (i.e. north, east, south and west). All photos should be uploaded and organised in an online file sharing platform[22].

In between two Verifications, any project can conduct Photo Monitoring and use the results, together with demonstration of the successful fulfilment of the *Progress Indicators* detailed in the PDD, to request the issuance of rPVCs.

Required outputs from Section 5.6.2:

- ***For Pathway One projects or any projects wishing to claim rPVCs***: Geolocated photographs taken at the centre of each Project Plot, facing in each cardinal direction (i.e. north, east, south, west), and uploaded to an online file sharing platform.

5.6.3 Calculate actual project CO_2 removals – PATHWAY ONE

5.6.3.1 Count living woody Mangroves within the Project Plots

At least every 5 years, projects must count all[23] living Mangrove Trees and Saplings (see Figure 2) in Project Plots that are within areas undergoing Restoration. The plot design used to count the Mangrove Trees in the *Project Area* prior to Restoration must be used again (i.e. if a project used a 7 m radius circular plot to complete Sections 5.1.2 and 5.1.3, a 7 m radius circular plot must be used throughout the *Crediting Period*).

The **average number of Mangrove Trees per Project Plot** and the **average number of Mangrove Saplings per Project Plot** must be calculated for **each Zone**. See the worked example below for further explanation. If the *Project Area* has not been divided into Zones, the average number of Mangrove Trees per Project Plot and the average number of Mangrove Saplings per Project Plot within the *Project Area* must be calculated instead.

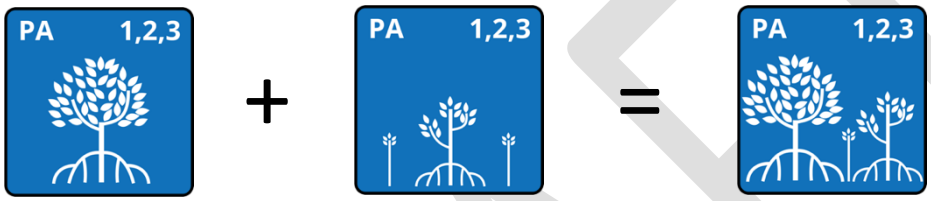
[21] There are many mobile applications that enable users to take GPS-stamped photographs. Examples include 'Conota – Timestamp GPS Camera' and 'Timemark:Photo Proof'. However, projects are not required to use such applications.
[22] Such as Google Drive or Dropbox.
[23] This includes Mangrove Trees and Saplings planted/restored due to the project and any baseline Mangrove Trees and samplings.

= Average number of Mangrove Trees in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

= Average number of baseline Mangrove Saplings in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

The sum of the average number of Mangrove Trees and the average number of Mangrove Saplings must be calculated to give the **average number of living Mangroves per plot in each Zone**.

Equation 13:



Where:

= Average number of living Mangroves in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

After year 10 of the project, if it can be demonstrated that access to the Project Plots is infeasible due to vegetation density, remotely sensed parameters (e.g. spectral indices from satellite sensors or tree counting using drone photography) can be used as a proxy for the number of living Mangroves within each Zone. Living Mangrove counting must still take place at least 10% of Project Plots within each Zone. The data from these plots together with the living Mangrove counting results from previous verifications must be used to demonstrate that there is a statistically significant (r^2 value greater than 0.7) correlation between the remotely sensed parameter and the number of living Mangroves.

Required outputs from Section 5.6.3.1:

Average number of Mangrove Trees in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

Average number of Mangrove Saplings in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

Average number of living Mangroves in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

Worked example – Section 5.6.3.1

The total number of Project Plots in the 'channel edge Mangroves' Zone is 13 (see Section 5.1.3). In Year 3 of the project, 6 of these plots are within areas undergoing Restoration.

The table below shows the number of Mangrove Trees and Saplings in each of these 6 plots.

Plot number	Number of Mangrove Trees	Number of Mangrove Saplings
1	2	184
2	3	174
3	4	170
4	3	142
5	4	167
6	2	163

The average number of Mangrove Trees within the Project Plots in Year 3 is:
(2 + 3 + 4 + 3 + 4 + 2) ÷ 6 = **3**

The average number of Mangrove Saplings within the Project Plots in Year 3 is:
(184 + 174 + 170 + 142 + 167 + 163) ÷ 6 = **167**

The average number of living Mangroves within the Project Plots in Year 3 is:
3 + 167 = **170**

Therefore, for the 'Channel edge Mangroves' Zone in Year 3 of the project:

= 3

= 167

= 170

5.6.3.2 Compare the average number of Mangroves in the Project Plots to the average number of Mangroves in the Target Plots

Every time the Mangroves are counted in the Project Plots, the average number of **living Mangroves** in each Zone of the *Project Area* needs to be compared to the average number of **living Mangroves** in the same Zone in the Target Area.

Equation 14:

Where:

= For each Zone, the ratio of the average number of living Mangroves in the Project Plots to the average number of living Mangroves in the Target Plots

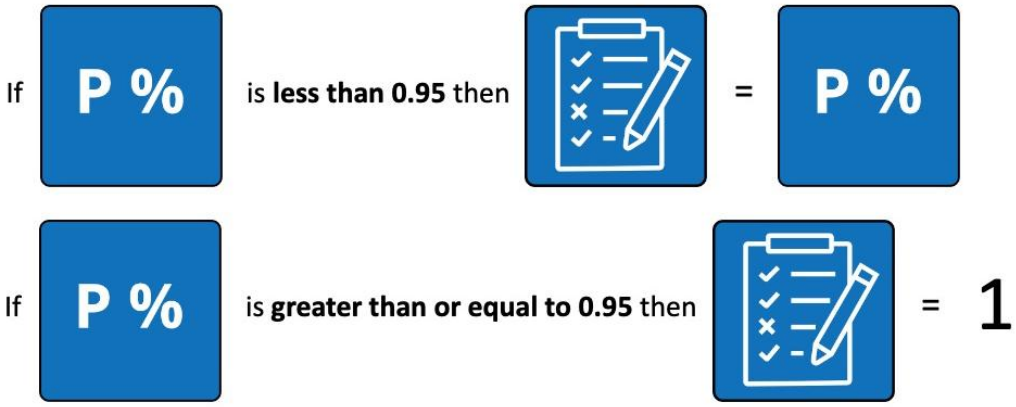
Required outputs from Section 5.6.3.2:

For each Zone, the ratio of the average number of living Mangroves in the Project Plots to the average number of living Mangroves in the Target Plots (unitless)

5.6.3.3 Calculate the performance adjustment

A performance adjustment must be applied if the average number of living Mangroves in the Project Plots are significantly less than the average number of living Mangroves in the Target Plots.

Equation 15:



Where:

= Performance adjustment for each Zone of the *Project Area* for each *Verification Period*

If tree counting does not take place every year (i.e. the *Verification Period* is longer than 1 year), the performance adjustment applies to all years since the last tree counting campaign.

See the worked example below for more information.

Required outputs from Section 5.6.3.3:

Performance adjustment for each Zone of the *Project Area* for each *Verification Period* (unitless)

Worked example – Section 5.6.3.1

Based on the tree counting calculations in Section 5.1.2, the average number of living Mangroves in the Target Plots in the 'Channel edge Mangroves' Zone is 182.

In Year 3 of the hypothetical project, the average number of living Mangroves in the Project Plots in the 'Channel edge Mangroves' Zone is 170.

= 182

= 170

Therefore:

= 170 ÷ 182 = 0.93

Because 0.93 is less than 0.95:

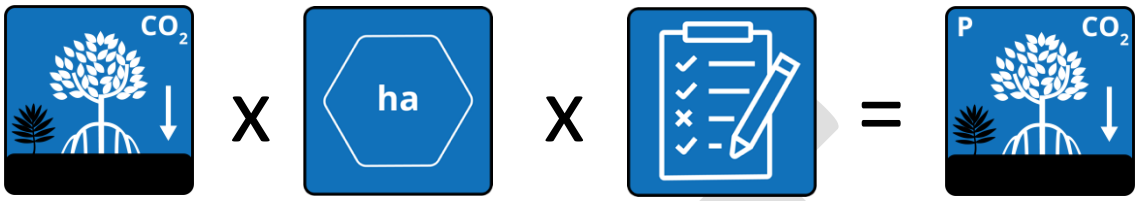
= 0.93

5.6.3.4 Calculate the actual project removals

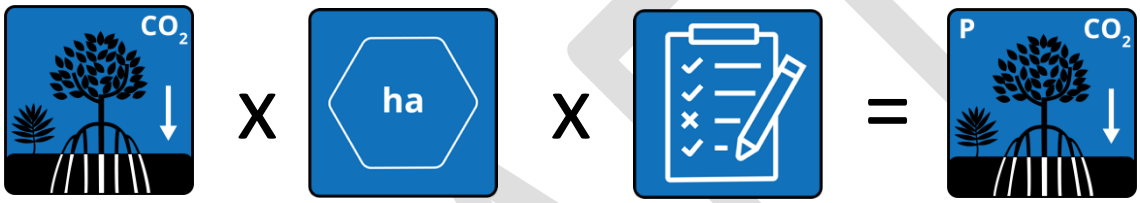
Actual project removals in each *Carbon Pool* are calculated using the same default values listed in Tables 1 and 2, depending on the IPCC climate Zone(s) that the *Project Area* is within.

For each Zone in the *Project Area* in each year of the *Verification Period*, actual CO_2 removals in each *Carbon Pool*, **within the time limits** explained in Tables 1 and 2, are calculated as follows:

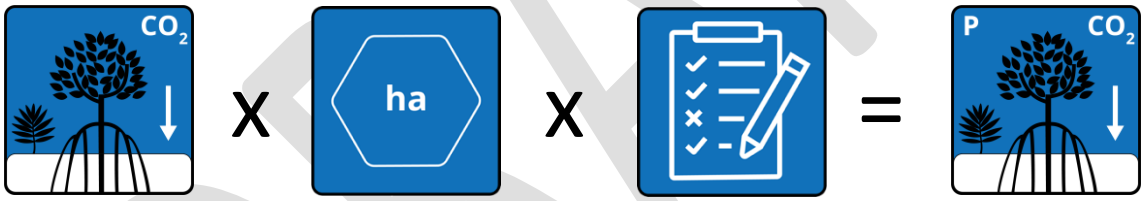
Equation 16:



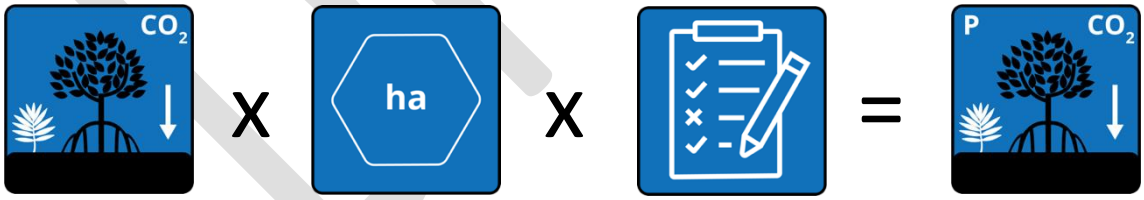
Equation 17:



Equation 18:

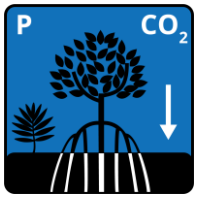


Equation 19:

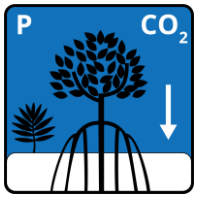


Where:

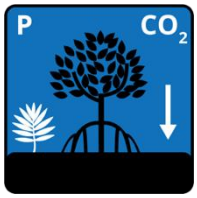
= Actual project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*



= Actual project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*



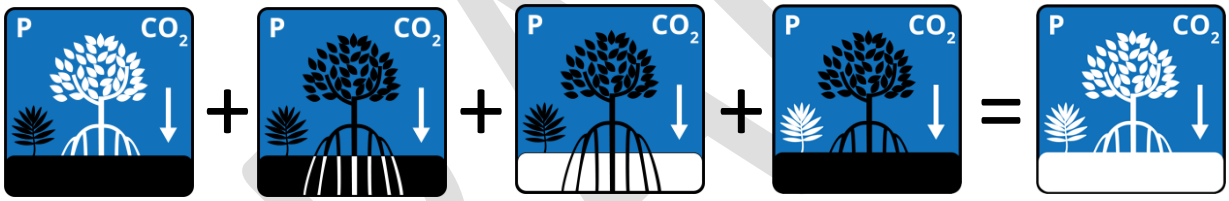
= Actual project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) each year of the *Verification Period*



= Actual project CO_2 removals in the aboveground non-woody biomass pool in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

Total actual project CO_2 removals are calculated as follows:

Equation 20:



Where:

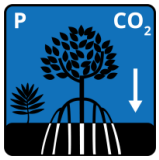
= **Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*.**

If the *Verification Period* is longer than 1 year, the total actual project CO_2 removals for the whole *Verification Period* is calculated by summing the annual CO_2 removals.

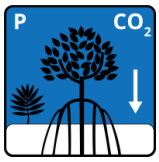
See the worked example below for more information.

Required outputs from Section 5.6.3.4:

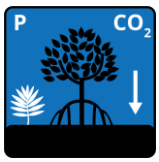
Actual project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual project CO_2 removals in the aboveground non-woody biomass pool in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Worked example – Section 5.6.3.4

The following table explains how actual project CO_2 removals for each *Carbon Pool* and the total expected project CO_2 removals from the Vegetation and Soil *Carbon Pools* are calculated for each year of two *Verification Periods*, using the 'Channel edge Mangroves' Zone from the hypothetical *Project Area* as an example.

The project counts Mangroves at the end Year 3 and Year 5. Therefore, the first *Verification Period* is from Year 1-3 and the second *Verification Period* is from Year 4-5. The ratio of Mangroves in the Project Plots compared to the Target Plots was 0.93 at the end of Year 3 and 0.97 at the end of Year 5. 0.93 is less than 0.95, therefore the performance adjustment is 0.93 for the first *Verification Period* (see Section 5.6.3.3). 0.97 is greater than 0.95, therefore the performance adjustment in the second *Verification Period* is 1.

The *Project Area* is in the Tropical Wet IPCC climate Zone, so the numbers in Table 1 are multiplied by the total area under Restoration in each year and the performance adjustment:

Channel edge mangroves									
Year	New area undergoing restoration (ha)	ha (ha)	P %		P CO2 (tCO_2e)	P CO2 (tCO_2e)	P CO2 (tCO_2e)	P CO2 (tCO_2e)	P CO2 (tCO_2e)
1	4	4		0.93	10.6 x 4 x 0.93 = 39	5.2 x 4 x 0.93 = 19	4.0 x 4 x 0.93 = 15	0 x 4 x 0.93 = 0	39 + 19 + 15 + 0 = 73
2	6	10		0.93	10.6 x 10 x 0.93 = 99	5.2 x 10 x 0.93 = 48	4.0 x 10 x 0.93 = 37	0 x 10 x 0.93 = 0	99 + 48 + 37 + 0 = 184
3	5	15	0.93	0.93	10.6 x 15 x 0.93 = 148	5.2 x 15 x 0.93 = 73	4.0 x 15 x 0.93 = 56	0 x 14 x 0.93 = 0	148 + 73 + 56 + 0 = 277
4	5	20		1	10.6 x 20 x 1 = 212	5.2 x 20 x 1 = 104	4.0 x 20 x 1 = 80	0 x 21 x 1 = 0	212 + 104 + 80 + 0 = 396
5	6	26	0.97	1	10.6 x 26 x 1 = 276	5.2 x 26 x 1 = 135	4.0 x 26 x 1 = 104	0 x 26 x 1 = 0	276 + 135 + 104 + 0 = 515

The total project CO_2 removals in all *Carbon Pools* during the first *Verification Period* (Years 1-3) is: 73 + 184 + 277 = **534**

The total project CO_2 removals in all *Carbon Pools* during the second *Verification Period* (Years 4-5) is: 396 + 515 = **911**

5.6.4 Calculate actual project CO_2 removals – PATHWAY TWO

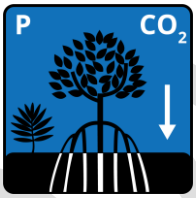
Projects following Pathway Two calculate actual project CO_2 removals through field measurements.

AR-TOOL14 version 4.2 must be used to estimate actual project removals in the aboveground woody biomass and belowground biomass pools, using Equation 21 and the variables defined in AR-TOOL14.

The Project Plots defined in Section 5.1.3 should be used to measure changes in biomass between years. However, AR-TOOL03 version 2.1 can be used to determine if only a subset of the Project Plots need to be monitored in order to collect statistically robust data. If only a subset of Project Plots are needed, these must be selected randomly.

When applying the procedures in AR-TOOL14, all[24] trees must be measured and monitored. Because of this, **an initial monitoring campaign must be conducted prior to the start of Restoration**. Thus, at the first monitoring campaign after the start of Restoration, t_1 is the date of the initial, pre-Restoration monitoring campaign.

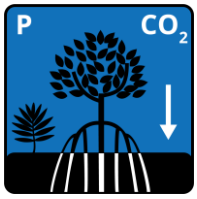
Equation 21:

+


=
$$\Delta C_{TREE,t} + \Delta C_{SHRUB,t}$$

Where:

= Actual project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*



= Actual project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

$\Delta C_{TREE,t}$ = Change in carbon stock in tree biomass within the project boundary in year t

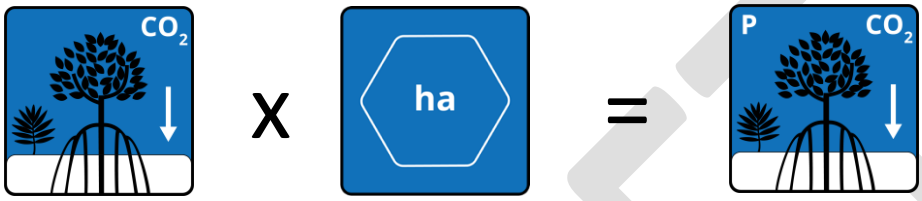
$\Delta C_{SHRUB,t}$ = Carbon stock in shrub biomass within the project boundary at a given point of time in year t

[24] This includes Mangrove planted/restored due to the project and any Pre-Project Mangroves.

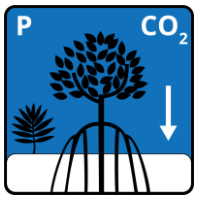
After year 10 of the project, if it can be demonstrated that access to the Project Plots is infeasible due to vegetation density, remotely sensed parameters (e.g. spectral indices from satellite or drone sensors) can be used as a proxy for vegetation biomass within each Zone. At least 10% of Project Plots within each Zone must still be measured in the field. The data from these plots together with the biomass monitoring results from previous verifications must be used to demonstrate that there is a statistically significant (r^2 value greater than 0.7) correlation between the remotely sensed parameter and vegetation biomass.

Removals in the soil organic *Carbon Pool* must be calculated for each Zone using the default value detailed in Table 1 (4.4 tCO_2e/ha/year) and the total area under Restoration:

Equation 22:

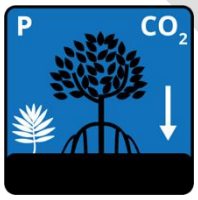


Where:



= Actual project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

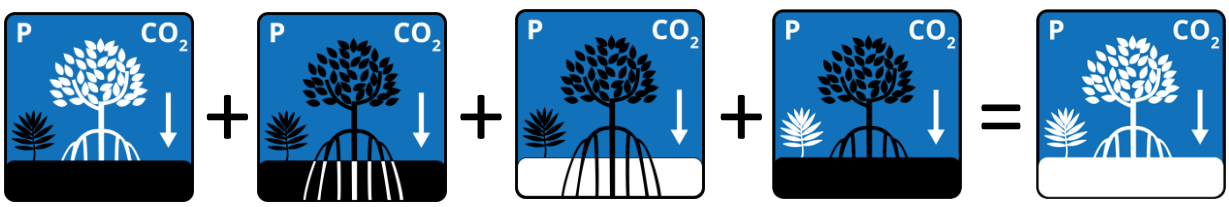
If aboveground non-woody biomass is not cleared due to project activities, monitoring of CO_2 removals in the aboveground non-woody biomass pool is optional for projects following Pathway Two. Projects wishing to quantify removals in this pool should follow the guidance in Howard et al., 2014[25] regarding carbon stock assessments of non-woody Mangroves and Mangrove-associate species to quantify:



= Actual project CO_2 removals in the aboveground non-woody biomass pool in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

Total actual project CO_2 removals are calculated as follows:

Equation 23:



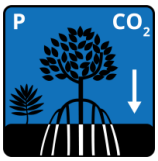
[25] https://www.thebluecarboninitiative.org/manual

Where:

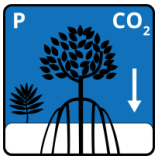
= Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

Required outputs from Section 5.6.4:

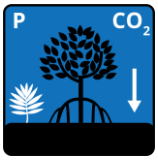
Actual project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual project CO_2 removals in the soil organic *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



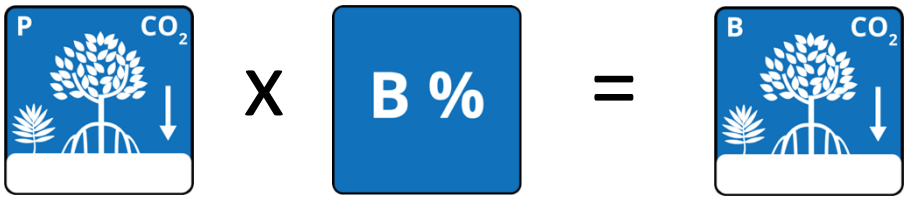
Actual project CO_2 removals in the aboveground non-woody biomass pool in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

5.6.5 Calculate the baseline removals

For each Zone in the *Project Area* in each year of the *Verification Period*, baseline CO_2 removals in all *Carbon Pools* are estimated by multiplying the actual project removals by the baseline adjustment:

Equation 24:



Where:

= Total baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

Required outputs from Section 5.6.5:

Total baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

5.7 Actual project emissions

Projects fulfilling the applicability conditions of PM00X and this module may produce emissions from the following *Carbon Pools* and emission sources:

- Aboveground woody biomass and belowground biomass
- Aboveground non-woody biomass
- Soil organic carbon
- Soil methanogenesis (methane (CH_4) emissions from the soil)
- CO_2 emissions from fossil fuel use

Projects can avoid accounting for one or more of the above emissions if they can demonstrate that the total excluded emissions are insignificant using AR-TOOL04 version 1.0.

5.7.1 Calculate actual project CO_2 emissions from the aboveground woody biomass and belowground biomass *Carbon Pools*

Only projects following Pathway One need to implement these procedures. For projects following Pathway Two, any negative changes in woody biomass carbon stocks in the *Project Area* will be accounted for in Equation 21.

At the same time the living Mangrove Trees and Saplings are being counted, projects following Pathway One must also count all Dead Mangroves in Project Plots that are undergoing restoration. The **average number of Dead Mangrove per Project Plot** must be calculated for **each Zone**. If the *Project Area* has not been divided into Zones, the average number of Dead Mangrove per Project Plot within the *Project Area* must be calculated instead.

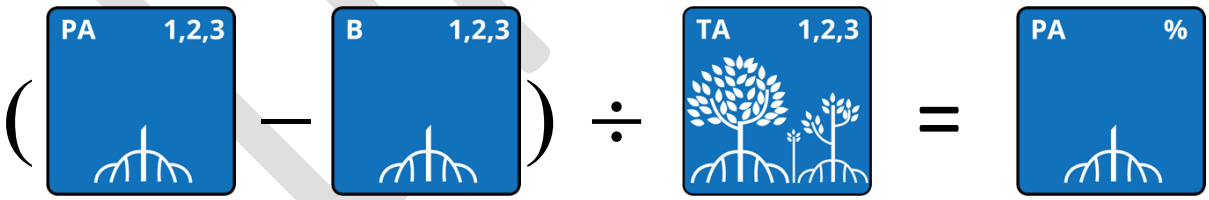
= Average number of Dead Mangroves in the Project Plots in each Zone in the *Project Area* at the time of *Verification*

For each Zone, this number must be compared to the number of Pre-Project Dead Mangroves. **If the number of Dead Mangroves at the time of *Verification* is <u>less than or equal to</u> the number of Pre-Project Dead Mangroves, no further action is required**.

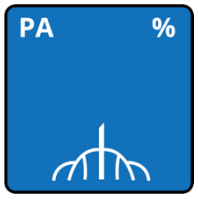
However, **if in any Zone the number of Dead Mangroves at the time of *Verification* is <u>greater than</u> the number of Pre-Project Dead Mangroves, the emissions due to biomass loss in the Zone(s) must be calculated**.

The following procedures can be used to do this. Factoring in the number of Pre-Project Dead Mangroves, the number of Dead Mangroves in the Zone(s) must be compared to the average number of living Mangroves in the same Zone(s) in the Target Area.

Equation 25:



Where:

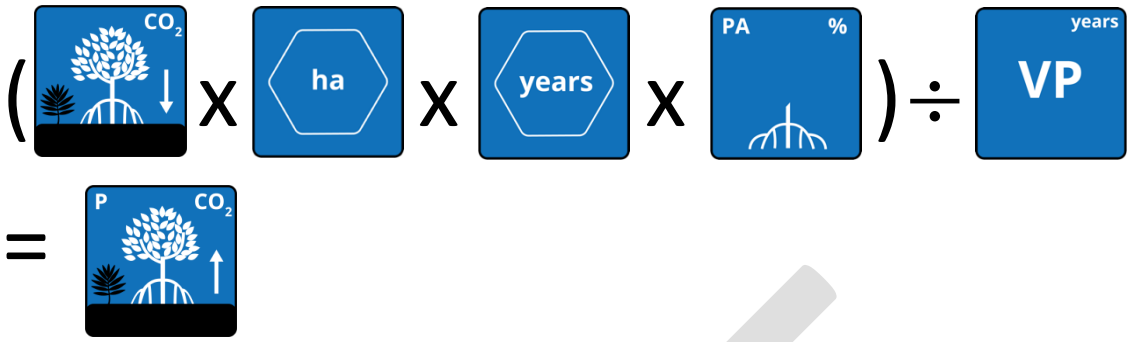


= The relative number of Dead Mangroves in the Project Plots at the time of *Verification* compared to average number of living Mangroves in the same Zone(s) in the Target Area (unitless)

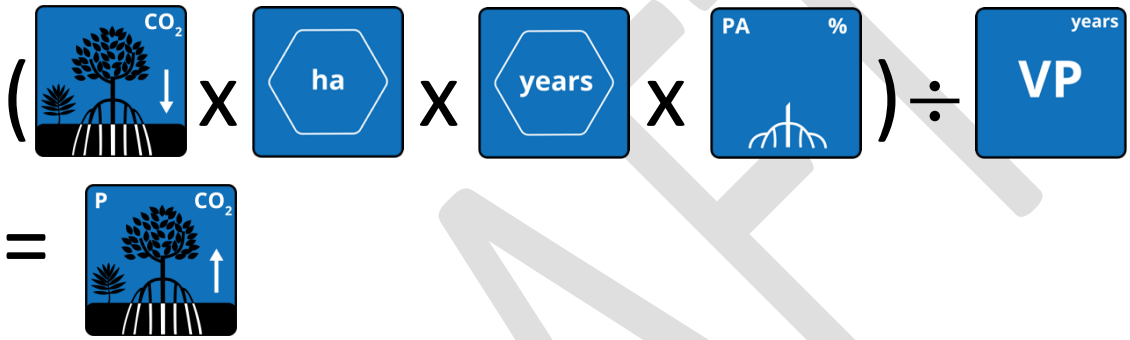
Once a biomass loss event has occurred in a Zone, at future *Verifications* projects must use the number of Dead Mangroves from the previous Verification in Equation 25, instead of the number of Pre-Project Dead Mangroves.

To calculate the emissions from the aboveground woody biomass and belowground biomass *Carbon Pools* in each relevant zone, Equations 26 and 27 must be used.

Equation 26:



Equation 27:

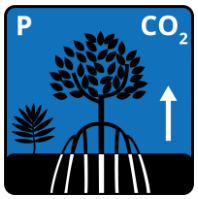


Where:

= The number of years since the start of restoration in each relevant Zone (years)

= Length of the *Verification Period* (years)

= Actual project CO_2 emissions in the aboveground woody biomass pool in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*



= Actual project CO_2 emissions in the belowground biomass pool in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

5.7.2 Calculate actual project CO_2 emissions from the aboveground non-woody biomass *Carbon Pool*

Only projects following Pathway Two and whose *Project Interventions* include the clearing of aboveground non-woody biomass are required to estimate emissions from this *Carbon Pool* in the project scenario.

For all other projects:

$= 0$

Where:

= Actual project CO_2 emissions in the aboveground non-woody biomass pool in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

Actual emissions from aboveground non-woody biomass should be estimated through field measurements in the Project Plots, following the plot selection guidance in Section 5.6.4.

Guidance on how to measure carbon stocks in non-woody biomass can be found in the Howard et al., 2014[26].

5.7.3 Calculate actual project CO_2 emissions from the soil organic carbon *Carbon Pool*

Only projects whose *Project Interventions* include the digging of channels (e.g. to restore hydrology) are required to account for emissions from the soil organic carbon pool.

For all other projects:

$= 0$

Where:

= Expected project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Crediting Period*

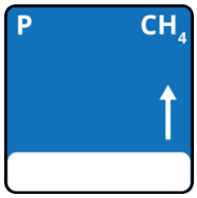
[26] https://www.thebluecarboninitiative.org/manual

Projects that dig channels must use PT##a (Tool to estimate emissions from the soil organic Carbon Pool due to channel digging in Mangroves) to estimate this parameter.

5.7.4 Calculate actual project methane (CH_4) emissions

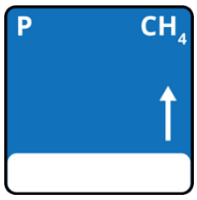
Only projects whose *Project Interventions* include the flooding of dry land where the salinity low point[27] is below 18 ppt are required to account for soil methanogenesis in the project scenario.

For all other projects:



$= 0$

Where:



= Actual project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period*

For each Zone of the *Project Area*, CH_4 emissions from soils may be estimated using either of the following:

- Field-collected data
- Peer-reviewed published data
- Emission factors from the Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories[28]

Guidance on how to monitor methane emissions can be found in the Howard et al., 2014[29].

Peer-reviewed published data must be limited to systems that are in the same or similar region as the *Project Area*, share similar geomorphic, hydrologic, and biological properties, and are under similar management regimes unless any differences should not have a substantial effect on methane emissions.

To convert methane emissions to tCO_2e, the most recent 100-year IPCC Global Warming Potential must be used. The AR6 2021 Global Warming Potential for methane is 27.2[30].

[27] The salinity low point should be measured on shallow pore water (within 30 cm from soil surface) using a handheld salinity refractometer or other accepted technology. The salinity low point must be calculated from observations that represent variation in salinity during periods of peak CH_4 emissions (e.g., during the growing season in temperate ecosystems or the wet season in tropical ecosystems).

[28] 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/

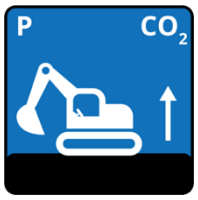
[29] https://www.thebluecarboninitiative.org/manual

[30] https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/

5.7.5 Calculate actual CO_2 emissions from fuel use

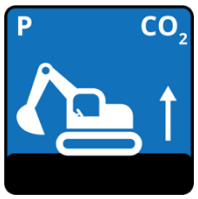
Only projects that involve the movement of soil with machinery (e.g. through the Restoration of hydrology in aquaculture ponds) are required to account for fossil fuel use in the project scenario.

For all other projects:



$= 0$

Where:



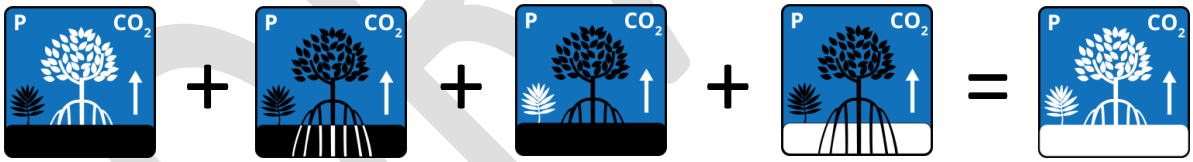
= Actual annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* (tCO2e) in each year of the *Verification Period* (parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0)

AR-TOOL05 version 1.0 must be used to estimate CO_2 emissions due to fossil fuels

5.7.6 Calculate total actual project emissions

The aboveground non-woody biomass and soil organic carbon pools are the only potential sources of emissions from *Carbon Pools* for projects fulfilling the applicability conditions of PM00X and this module. Therefore, the total actual project emissions from *Carbon Pools* are calculated as follows:

Equation 28:

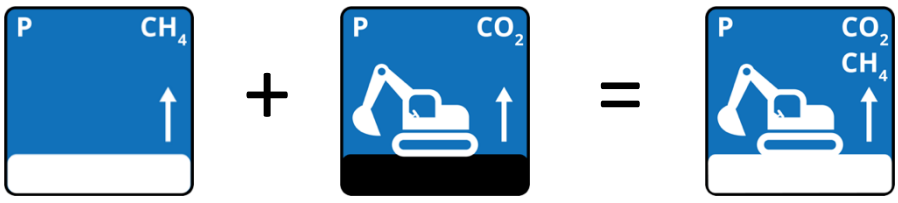


Where:

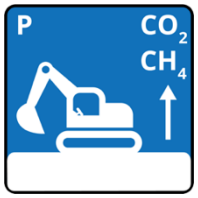
= **Total actual project emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period***

Total actual project emissions from emissions sources are calculated as follows:

Equation 29:



Where:

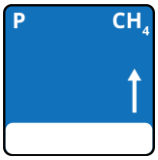


= **Total actual project emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period***

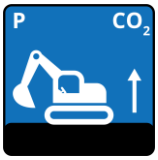
Required outputs from Section 5.7:

Actual project CO_2 emissions in the aboveground non-woody biomass *Carbon Pool* in each relevant Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Actual project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)

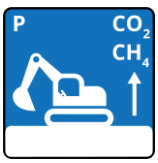


Actual project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Actual annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* in each year of the *Verification Period* (parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0) (tCO_2e)

Total actual project emissions in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period* (tCO_2e)



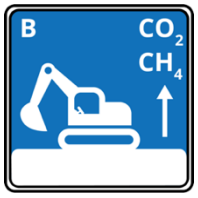
Total actual project emissions from all emission sources in each Zone of the *Project Area* (tCO_2e) for each year of the *Verification Period* (tCO_2e)

5.8 Calculate total actual removals and emissions across all Zones

The final step is to calculate the total actual removals and emissions in the baseline and project scenarios across **all Zones** for **each year of the *Verification Period***. This is done by summing the values in all Zones for the following parameters:

= **Total baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period***

= **Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period.*** The applicability conditions and assumptions of this module mean this parameter = 0.



= **Total actual baseline emissions from all emission sources across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period.*** The applicability conditions and assumptions of this module mean this parameter = 0.

= **Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period.***

= **Total actual project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period.***

= **Total actual project emissions from all emission sources across all Zones of the *Project Area* (tCO_2e) for each year of the *Verification Period.***

These parameters are then used in PM00X to estimate the *Carbon Benefit* of the project.

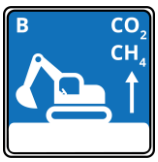
For each year of the *Verification Period*, these values must be presented in the *Annual Report* prior to *Verification* in table format[31].

[31] This spreadsheet shows an example table that is suitable for the *Annual Report* (see the 'Actual' sheet), using the hypothetical *Project Area* referenced throughout the worked examples in this module. The equations are for explanation, in line with the other worked examples, and do not need to be visible in the table in the

Required outputs from Section 5.8:

Total actual baseline CO_2 removals from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)



Total actual baseline emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)

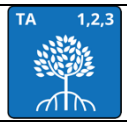
Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)

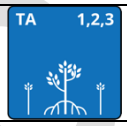
Total actual project emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Total actual project emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period* (tCO_2e)

Annual Report: https://docs.google.com/spreadsheets/d/1F3Vg1WYde7PX_KgBQZIDCDHY7IArH0VDWRVDLlCEZyE/edit?usp=sharing

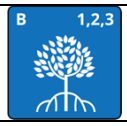
6 Parameters

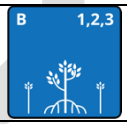
Data/Parameter	
Units	Number
Description	Average number of Mangrove Trees in the Target Plots in each Zone in the Target Area.
Equations	1, 3
Source	Field counts of Mangrove Trees in 10m x 10m square plots or 7m radius circular plots in the Target Area. For Target Areas or Zones smaller than 200 hectares, at least one Target Plot per 20 hectares must be established and each Zone must have a minimum of 2 Target Plots. For Target Areas or Zones larger than 200 hectares, at least 10 Target Plots must be established. Plots must be randomly located.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Establish the baseline adjustment and monitor the success of reforestation
Comments	N/A

Data/Parameter	
Units	Number
Description	Average number of Mangrove Saplings in the Target Plots in each Zone in the Target Area.
Equations	1
Source	Field counts of Mangrove Saplings in 10m x 10m square plots or 7m radius circular plots in the Target Area. For Target Areas or Zones smaller than 200 hectares, at least one Target Plot per 20 hectares must be established and each Zone must have a minimum of 2 Target Plots. For Target Areas or Zones larger than 200 hectares, at least 10 Target Plots must be established. Plots must be randomly located.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Establish the baseline adjustment and monitor the success of reforestation
Comments	N/A

Data/Parameter	

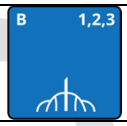
Units	Number
Description	Average number of living Mangroves in the Target Plots in each Zone in the Target Area.
Equations	1, 4, 14, 25
Source	See Section 5.1.2.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.1.2.
Purpose of Data	Establish the baseline adjustment and monitor the success of reforestation
Comments	N/A

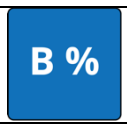
Data/Parameter	
Units	Number
Description	Average number of Pre-Project Mangrove Trees in the Project Plots in each Zone in the *Project Area*.
Equations	2, 3
Source	Field counts of Mangrove Trees in 10m x 10m square plots or 7m radius circular plots in the *Project Area*. For a *Project Area* or Zone smaller than 200 hectares, at least one Project Plot per 2 hectares must be established and each Zone must have a minimum of 10 Project Plots. For *Project Area*s or Zones larger than 200 hectares, at least 100 Project Plots must be established. Plots must be randomly located.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Establish the baseline adjustment.
Comments	N/A

Data/Parameter	
Units	Number
Description	Average number of Pre-Project Mangrove Saplings in the Project Plots in each Zone in the *Project Area*.
Equations	2
Source	Field counts of Mangrove Saplings in 10m x 10m square plots or 7m radius circular plots in the *Project Area*. For a *Project Area* or Zone smaller than 200 hectares, at least one Project Plot per 2 hectares must be established and each Zone must have a minimum of 10 Project Plots. For *Project Area*s or Zones larger than 200 hectares, at least 100 Project Plots must be established. Plots must be randomly located.

Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Establish the baseline adjustment.
Comments	N/A

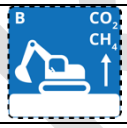
Data/Parameter	
Units	Number
Description	Average number of Pre-Project living Mangroves in the Project Plots in each Zone in the Project Area.
Equations	2, 4
Source	See Section 5.1.3.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.1.3.
Purpose of Data	Establish the baseline adjustment.
Comments	N/A

Data/Parameter	
Units	Number
Description	Average number of Pre-Project Dead Mangroves in the Project Plots in each Zone in the *Project Area*.
Equations	25
Source	See Section 5.1.3.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.1.3.
Purpose of Data	Calculate emissions from aboveground woody and belowground biomass due to tree loss. Only required for Pathway One projects.
Comments	N/A

Data/Parameter	
Units	Unitless
Description	Baseline adjustment.
Equations	3, 4, 10, 24
Source	See Section 5.1.3.
Value	N/A

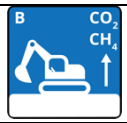
Justification of choice of data or description of measurement methods and procedures applied	A ratio of vegetation present in the *Project Area* compared to the Target Area, defined depending on the baseline scenario, which represents the relative presence of Pre-Project trees that cannot be attributed to the project's activities and the likelihood of natural regeneration in the baseline scenario.
Purpose of Data	Establish the baseline.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	
Source	See Section 5.2.3.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

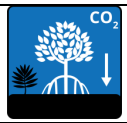
Data/Parameter	
Units	tCO_2e
Description	Total expected baseline emissions from all emission sources in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	
Source	See Section 5.2.3.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating expected baseline emissions from the *Emission Sources*.
Comments	N/A

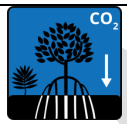
Data/Parameter	
Units	tCO_2e

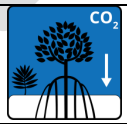
Description	Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	
Source	See Section 5.2.3.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario, in the absence of the Project Intervention, are conservatively excluded from this module.
Purpose of Data	Estimating actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline emissions from all emission sources in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	
Source	See Section 5.2.3.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario, in the absence of the Project Intervention, are conservatively excluded from this module.
Purpose of Data	Estimating actual baseline emissions from the *Emission Sources*.
Comments	N/A

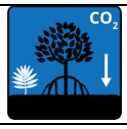
Data/Parameter	
Units	ha
Description	Total area in each Zone that is expected to be undergoing Restoration in each year of the *Crediting Period.*
Equations	5-8
Source	See Section 5.3.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Participatory mapping and/or Restoration/rehabilitation plans.
Purpose of Data	Estimating expected greenhouse gas emissions and removals.
Comments	N/A

Data/Parameter	
Units	$tCO_2e/ha/year$
Description	Annual per hectare CO_2 removals in aboveground woody biomass.
Equations	5, 9, 16
Source	Projects following Pathway One must use the default values detailed in Table 1 or 2. Projects following Pathway Two can use the default values in Table 1 or 2, or model tree growth and stand development, following the procedures in AR-TOOL14 version 4.2 Section 8.2.
Value	See Table 1.
Justification of choice of data or description of measurement methods and procedures applied	See Annex One and PU001.
Purpose of Data	Estimating project CO_2 removals.
Comments	N/A

Data/Parameter	
Units	$tCO_2e/ha/year$
Description	Annual per hectare CO_2 removals in belowground biomass.
Equations	6, 9, 17
Source	Projects following Pathway One must use the default values detailed in Table 1 or 2. Projects following Pathway Two can use the default values in Table 1 or 2, or model tree growth and stand development, following the procedures in AR-TOOL14 version 4.2 Section 8.2.
Value	See Table 1.
Justification of choice of data or description of measurement methods and procedures applied	See Annex One and PU001.
Purpose of Data	Estimating project CO_2 removals.
Comments	N/A

Data/Parameter	
Units	$tCO_2e/ha/year$
Description	Annual per hectare CO_2 removals in the soil organic carbon pool.
Equations	7, 9, 19
Source	Default values detailed in Tables 1 and 2.
Value	4.0
Justification of choice of data or description of	See Annex One.

measurement methods and procedures applied	
Purpose of Data	Estimating project CO_2 removals.
Comments	N/A

Data/Parameter	
Units	$tCO_2e/ha/year$
Description	Annual per hectare CO_2 removals in aboveground non-woody biomass.
Equations	8-9, 19
Source	N/A
Value	0
Justification of choice of data or description of measurement methods and procedures applied	CO_2 removals in the aboveground non-woody biomass *Carbon Pool* are conservatively assumed to be zero.
Purpose of Data	Estimating project CO_2 removals.
Comments	N/A

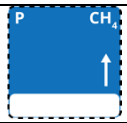
Data/Parameter	
Units	tCO_2e
Description	Total expected project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	9-10
Source	See Section 5.3.2.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.3.2.
Purpose of Data	Estimating expected project CO_2 removals from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

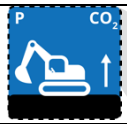
Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	10

Source	See Section 5.3.3.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.3.3.
Purpose of Data	Estimating expected baseline CO_2 removals from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Expected project CO_2 emissions in the aboveground non-woody biomass *Carbon Pool* in each relevant Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	11
Source	Guidance on how to measure carbon stocks in non-woody biomass can be found in the Howard et al., 2014.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway Two and whose *Project Interventions* include the clearing of aboveground non-woody biomass are required to estimate emissions from this *Carbon Pool* in the project scenario.
Purpose of Data	Estimating expected project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

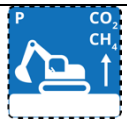
Data/Parameter	
Units	tCO_2e
Description	Expected project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	11
Source	PT##a.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects whose *Project Interventions* include the digging of channels (e.g. to restore hydrology) are required to account for emissions from the soil organic carbon pool.
Purpose of Data	Estimating expected project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Expected project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	12
Source	Peer-reviewed published data or emission factors from the Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects whose *Project Interventions* include the flooding of dry land where the salinity low point is below 18 ppt are required to account for soil methanogenesis in the project scenario.
Purpose of Data	Estimating expected project emissions from the *Emission Sources*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Expected annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* in each year of the *Crediting Period*
Equations	12
Source	Parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects that involve the movement of soil with machinery (e.g. through the Restoration of hydrology in aquaculture ponds) are required to account for fossil fuel use in the project scenario.
Purpose of Data	Estimating expected project emissions from the *Emission Sources*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected project CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	11
Source	See Section 5.4.5.
Value	N/A
Justification of choice of data or description of	See Section 5.4.5.

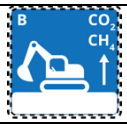
measurement methods and procedures applied	
Purpose of Data	Estimating expected project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected project emissions from all emission sources in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	12
Source	See Section 5.4.5.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.4.5.
Purpose of Data	Estimating expected project emissions from the *Emission Sources*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A
Source	See Section 5.5.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.5.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A

Source	See Section 5.5.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A
Source	See Section 5.5.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A
Source	See Section 5.5.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.5.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e

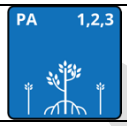
Description	Total expected project CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A
Source	See Section 5.5.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.5.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected project CO_2 emissions from all emission sources across all Zones of the *Project Area* for each year of the *Crediting Period*.
Equations	N/A
Source	See Section 5.5.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.5.
Purpose of Data	Estimating total expected emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	ha
Description	Total area in each Zone that is undergoing Restoration in each year of the *Verification Period.*
Equations	16-19, 22, 26, 27
Source	See Section 5.6.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Participatory mapping and/or GIS analysis.
Purpose of Data	Estimating expected greenhouse gas emissions and removals.
Comments	N/A

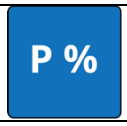
Data/Parameter	

Units	Number
Description	Average number of Mangrove Trees in the Project Plots in each Zone in the *Project Area* at the time of *Verification*.
Equations	13
Source	Field counts of Mangrove Trees in 10m x 10m square plots or 7m radius circular plots in the *Project Area*. For a *Project Area* or Zone smaller than 200 hectares, at least one Project Plot per 2 hectares must be established and each Zone must have a minimum of 10 Project Plots. For *Project Area*s or Zones larger than 200 hectares, at least 100 Project Plots must be established. Plots must be randomly located.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Estimating project performance and CO_2 removals.
Comments	N/A

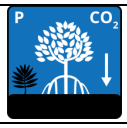
Data/Parameter	
Units	Number
Description	Average number of Mangrove Saplings in the Project Plots in each Zone in the *Project Area* at the time of *Verification*.
Equations	13
Source	Field counts of Mangrove Saplings in 10m x 10m square plots or 7m radius circular plots in the *Project Area*. For a *Project Area* or Zone smaller than 200 hectares, at least one Project Plot per 2 hectares must be established and each Zone must have a minimum of 10 Project Plots. For *Project Area*s or Zones larger than 200 hectares, at least 100 Project Plots must be established. Plots must be randomly located.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Established field measurement protocol. Plot design follows best practice as outlined in Howard et al., 2014.
Purpose of Data	Estimating project performance and CO_2 removals.
Comments	N/A

Data/Parameter	
Units	Number
Description	Average number of living Mangroves in the Project Plots in each Zone in the Project Area at the time of *Verification*.
Equations	13-14
Source	See Section 5.6.3.1.
Value	N/A

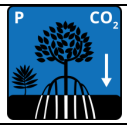
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.6.3.1.
Purpose of Data	Estimating project performance and CO_2 removals.
Comments	N/A

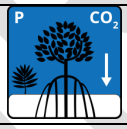
Data/Parameter	
Units	Unitless
Description	For each Zone, the ratio of the average number of living Mangroves in the Project Plots to the average number of living Mangroves in the Target Plots.
Equations	14-15
Source	See Section 5.6.3.2.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Comparing the number of living Mangroves in the Project Plots to the number of living Mangroves in the Target Plots provides information regarding the performance of the project, and how well the *Project Area* is progressing towards the end-state of the Target Area.
Purpose of Data	Estimating project performance.
Comments	N/A

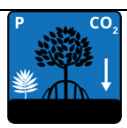
Data/Parameter	
Units	Unitless
Description	Performance adjustment for each Zone of the *Project Area* for each *Verification Period*.
Equations	15-19
Source	See Section 5.6.3.2.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	A performance adjustment must be applied if the average number of living Mangroves in the Project Plots are significantly less than the average number of living Mangroves in the Target Plots.
Purpose of Data	Estimating project performance and CO_2 removals.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 removals in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	16, 20, 21, 23
Source	See Sections 5.6.3.4 and .

Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Sections 5.6.3.4 and .
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 removals in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	17, 20, 21, 23
Source	See Sections 5.6.3.4 and .
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Sections 5.6.3.4 and .
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 removals in the soil organic carbon pool in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	18, 20, 22-23
Source	See Sections 5.6.3.4 and .
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Sections 5.6.3.4 and .
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

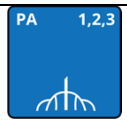
Data/Parameter	

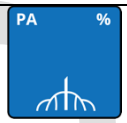
Units	tCO_2e
Description	Actual project CO_2 removals in the aboveground non-woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	19-20, 23
Source	See Sections 5.6.3.4 and .
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Sections 5.6.3.4 and .
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual project CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	20, 23, 24
Source	See Sections 5.6.3.4 and 5.6.4.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Sections 5.6.3.4 and 5.6.4.
Purpose of Data	Estimating actual project CO_2 removals from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	24
Source	See Section 5.6.5.
Value	N/A
Justification of choice of data or description of	See Section 5.6.5.

measurement methods and procedures applied	
Purpose of Data	Estimating actual baseline CO_2 removals from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	Number
Description	Average number of Dead Mangroves in the Project Plots in each Zone in the *Project Area* at the time of *Verification*.
Equations	25
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

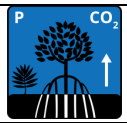
Data/Parameter	
Units	Unitless
Description	The relative number of Dead Mangroves in the Project Plots at the time of *Verification* compared to average number of living Mangroves in the same Zone(s) in the Target Area.
Equations	25, 26, 27
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One that see an increase in the number of Dead Mangroves in Project Plots are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	Years
Description	The number of years since the start of restoration in each relevant Zone.

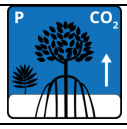
Equations	26, 27
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One that see an increase in the number of Dead Mangroves in Project Plots are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	Years
Description	The length of the *Verification Period*.
Equations	26, 27
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One that see an increase in the number of Dead Mangroves in Project Plots are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

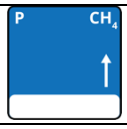
Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 emissions in the aboveground woody biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	26, 28
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One that see an increase in the number of Dead Mangroves in Project Plots are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

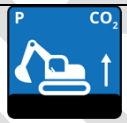
Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 emissions in the belowground biomass *Carbon Pool* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	27, 28
Source	See Section 5.7.1.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway One that see an increase in the number of Dead Mangroves in Project Plots are required to calculate this parameter.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

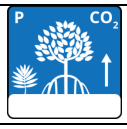
Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 emissions in the aboveground non-woody biomass *Carbon Pool* in each relevant Zone of the *Project Area* for each year of the *Verification Period*.
Equations	28
Source	Guidance on how to measure carbon stocks in non-woody biomass can be found in the Howard et al., 2014.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects following Pathway Two and whose *Project Interventions* include the clearing of aboveground non-woody biomass are required to estimate emissions from this *Carbon Pool* in the project scenario.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Actual project CO_2 emissions in the soil organic carbon pool in each relevant Zone of the *Project Area* for each year of the *Verification Period*.
Equations	28
Source	PT##a.
Value	N/A

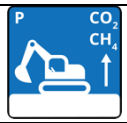
Justification of choice of data or description of measurement methods and procedures applied	Only projects whose *Project Interventions* include the digging of channels (e.g. to restore hydrology) are required to account for emissions from the soil organic carbon pool.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

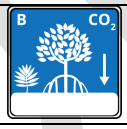
Data/Parameter	
Units	tCO_2e
Description	Expected project emissions due to soil methanogenesis in each relevant Zone of the *Project Area* for each year of the *Verification Period*.
Equations	29
Source	Peer-reviewed published data or emission factors from the Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects whose *Project Interventions* include the flooding of dry land where the salinity low point is below 18 ppt are required to account for soil methanogenesis in the project scenario.
Purpose of Data	Estimating actual project emissions from the *Emission Sources*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Actual annual CO_2 emissions due to fossil fuel use in each Zone of the *Project Area* in each year of the *Verification Period*
Equations	29
Source	Parameter $ET_{FC,y}$ in AR-TOOL05 version 1.0.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	Only projects that involve the movement of soil with machinery (e.g. through the Restoration of hydrology in aquaculture ponds) are required to account for fossil fuel use in the project scenario.
Purpose of Data	Estimating actual project emissions from the *Emission Sources*.
Comments	N/A

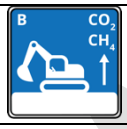
Data/Parameter	
Units	tCO_2e

Description	Total actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools* in each Zone of the *Project Area* for each year of the *Verification Period*.
Equations	28
Source	See Section 5.7.6.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.7.6.
Purpose of Data	Estimating actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total expected project emissions from all emission sources in each Zone of the *Project Area* for each year of the *Crediting Period*.
Equations	29
Source	See Section 5.7.6.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.7.6.
Purpose of Data	Estimating expected project emissions from the *Emission Sources*.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.8.
Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline CO_2 emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	0
Justification of choice of data or description of measurement methods and procedures applied	Any GHG emissions that would occur in the baseline scenario are conservatively excluded from this module.
Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual baseline CO_2 removals in the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.8.

Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual project CO_2 emissions from the Vegetation and Soil *Carbon Pools* across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.8.
Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

Data/Parameter	
Units	tCO_2e
Description	Total actual project CO_2 emissions from all emission sources across all Zones of the *Project Area* for each year of the *Verification Period*.
Equations	N/A
Source	See Section 5.8.
Value	N/A
Justification of choice of data or description of measurement methods and procedures applied	See Section 5.8.
Purpose of Data	Estimating total actual emissions and removals across all Zones.
Comments	N/A

7 References

PT##a – Tool for calculating emissions due to channelling in mangrove ecosystems

PT##b – Uncertainty Calculator for Pathway One in PU##b

Plan Vivo Climate Glossary version 1.3. Available from: https://www.planvivo.org/pv-climate-documentation

AR-AM0014 version 3.0 – Afforestation and reforestation of degraded Mangrove habitats. Available from: https://cdm.unfccc.int/methodologies/DB/KMH6O8T6RL3P5XKNBQE2N359QG7KOE

AR-TOOL03 version 2.1 – Calculation of the number of sample plots for measurements within A/R CDM project activities. Available from: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-03-v2.1.0.pdf/history_view

AR-TOOL04 version 1.0 – Tool for testing significance of GHG emissions in A/R CDM project activities. Available from: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-amtool-04-v1.pdf/history_view

AR-TOOL05 version 1.0 – Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities. Available from: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-05-v1.pdf/history_view

AR-TOOL14 version 4.2 – Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities. Available from: https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-14-v2.1.0.pdf/history_view

2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands Methodological Guidance on Lands with Wet and Drained Soils, and Constructed Wetlands for Wastewater Treatment. Available from: https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/

Alongi and Zimmerman, 2024. Blue carbon biomass stocks but not sediment stocks or burial rates exhibit global patterns in re-established mangrove chronosequences: a meta-analysis. https://www.int-res.com/abstracts/meps/v733/meps14560

Beeston et al., 2023. Best Practice Guidelines for Mangrove Restoration. https://www.Mangrovealliance.org/wp-content/uploads/2023/10/Best-Practice-for-Mangrove-Restoration-Guidelines-v2.pdf

Grimm et al., 2024. Including Local Ecological Knowledge (LEK) in Mangrove Conservation & Restoration: A Best-Practice Guide for Practitioners and Researchers. https://www.mangrovealliance.org/wp-content/uploads/2024/02/LEK-Guide-Master-Book_Final.pdf

Howard et al., 2014. Coastal Blue Carbon; methods for assessing carbon stocks and emissions factors in Mangroves, tidal salt marshes, and seagrass meadows. https://www.thebluecarboninitiative.org/manual

SER (Society for Ecological Restoration International), 2004**.** The SER International Primer on Ecological Restoration. Society for Ecological Restoration International Science & Policy Working Group. https://www.ser.org/page/SERDocuments

Spalding et al., 2007. Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. https://academic.oup.com/bioscience/article-abstract/57/7/573/238419?redirectedFrom=fulltext

Wortley, L. et al., 2013. Evaluating ecological restoration success: A review of the literature. https://onlinelibrary.wiley.com/doi/abs/10.1111/rec.12028

Annex One – Justification for default values

Research into mangrove biomass growth curves

The 2013 Wetlands Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories details Tier I values for removals in aboveground woody biomass and belowground biomass, depending on climate zone (Tropical Wet and Tropical Dry). The time limits for application can be based on the Tier I maximum mangrove biomass stocks in the same Wetlands Supplement. Beyond this, several recent, comprehensive and very relevant meta-analyses were found and reviewed. In particular, Song et al., 2023, Bourgeois et al., 2024 and Alongi and Zimmerman, 2024.

Song et al. collated peer-reviewed datasets to look at the difference in the carbon benefit of mangrove reforestation compared to mangrove afforestation. Bourgeois et al. similarly collated peer-reviewed datasets, as well as reaching out to authors to ensure they had the full datasets where possible, but instead focused on comparing the carbon stocks in restored mangroves to those in intact mangroves. Alongi and Zimmerman also conducted a meta-analysis of published mangrove reforestation carbon stock data but instead focused on understanding how carbon stocks and soil carbon burial rates varied according to dominant species, forest age, latitude, sediment % total organic carbon, salinity, rainfall, and temperature.

Whilst all papers found trends with varying levels of significance between carbon stocks and forest age, and Song et al. and Alongi and Zimmerman looked into the relationships between carbon stocks and various ecological variables, they all analysed their data at a global level. Given the known strong variations in mangrove growth globally, if possible it is preferable to provide more than one set of default values, similar to how the IPCC separates between tropical wet and tropical dry climates.

Both Song et al. and Alongi and Zimmerman shared the treated data behind their analyses as supplementary information. Such rich datasets enable further analysis, beyond the trends published in the papers. However, Song et al. only look at SOC carbon stocks in the top 1 metre whilst Alongi and Zimmerman also look at soil carbon burial rates, which are more relevant in the context of SOC accumulation due to mangrove restoration. Also, Alongi and Zimmerman include data published in 2023, so their dataset constitutes a slightly more concurrent collation of published data compared to Song et al.. Lastly, Alongi and Zimmerman include data from naturally regenerating mangroves, as well as those planted, and such data is relevant to the assisted natural regeneration techniques promoted by many mangrove practitioners as best practise. Therefore, it was decided to use the Alongi and Zimmerman dataset for further exploration.

The analysis of the Alongi and Zimmerman dataset can be found here. The analysis relevant to this section can be found in the 'AGC and BGC stocks_PV' sheet.

There are three components to the IPCC Tier I values: the above-ground biomass stocks in mangroves, used to estimate the maximum biomass stock that restored mangroves can reach; the growth rate of above-ground biomass; and the ratio of below- to above-ground biomass (roots:shoots). In order to enable testing of the roots:shoots ratio, the dataset was filtered to only include entries that provide both above- and below-ground carbon stocks (AGC and BGC respectively). This left 313 datapoints. The relevant IPCC climate zone was assigned to each entry. A meaningful number of datapoints were not available for the tropical dry climate zone. Thus, this analysis focuses on the data from the tropical wet climate zone. The maximum length of the Project Crediting Period for a PVC project is 50 years. Therefore, only datapoints with a stand age of 50 years

or less were included in the analysis. This helped to remove some of the variation seen in mature stands.

For each forest age included in the dataset, the average AGC stock was calculated. Whilst the datapoints are dispersed, when these average AGC stocks are plotted against those predicted by the IPCC Tier I values (see Figure A1 below, blue dots and green line respectively), it is clear that the IPCC values are consistently higher than those in the dataset collated by Alongi and Zimmerman. An s-shaped trend is not immediately obvious from the climate zone dataset but it does exhibit a linear trend ($y = 2.887x$) with an R^2 value of 0.77. A clear s-curve trend may not be expected from a dataset covering such a wide geographic area, but even when the dataset is analysed by country (see 'AGC and BGC stocks_Country' sheet for a simplistic analysis), most country's data follows a broadly linear trend and none exhibit an s-shaped trend.

This advocates for two initial conclusions: **the IPCC Tier I values are not conservative, but the application of a linear trend (constant rate) for biomass growth is not unreasonable**. Alongi and Zimmerman also note that many published datasets suggest linear trends between stand age and above-ground carbon stocks (see Table 2 in the publication).

Referring to the tropical wet climate zone dataset, the mean growth rate (slope of the linear trend) is 2.9 tC/ha/year, which is **equivalent to 65% of the IPCC Tier I value** (herein, 'adjusted IPCC trend').

Song et al. estimate non-linear AGC growth curves in reforested and afforested stands (see Figure 4 in the publication). These are shown as dark blue and grey lines respectively in Figure A1 below. As can be seen, whilst these trends are s-curves, in all but the first 6 years the reforestation curve from Song et al. is significantly more aggressive than the adjusted IPCC trend (yellow curve in Figure A1 below), with most field datapoints sitting below the curve. This indicates that it would not be conservative to use the Song et al. reforestation curve for the default growth rates in the module. Whilst the afforestation curve is more in-line with the datapoints from Alongi and Zimmerman and slightly more conservative than the adjusted IPCC trend in the first 6 years (see Figure A2 below), over 20 years (the most common length of a PVC project) the adjusted IPCC trend is more conservative. The afforestation trend in Song et al. predicts that 70 tC/ha will accumulate in the biomass over 20 years, while the adjusted IPCC trend predicts 58 tC/ha.

Whilst both the Song et al. curves are slightly more conservative than the adjusted IPCC trend in the first 6 years of growth, with the exception of year 7 the adjusted IPCC curve is still below all the averaged AGC values in Alongi and Zimmerman for forest ages 1-10 years.

Bourgeois et al. provide mean AGC values for 5-year forest age ranges (see Table S1 in the publication). The linear trend ($R^2 = 0.99$) of these highly aggregated values gives a higher average annual AGC growth rate (3.47 tC/ha/year) compared to the datapoints in Alongi and the adjusted IPCC trend (2.9 tC/ha/year).

Therefore, it is proposed that **65% of the IPCC Tier I value (2.9 tC/ha/year) is used as the default AGC accumulation rate for projects in the IPCC tropical wet climate zone**.

Whilst there is insufficient data in Alongi and Zimmerman to analyse AGC trends at sites in the tropical dry climate zone, it is deemed consistent and conservative to apply **the same 65% adjustment to the IPCC Tier I AGC growth rates for the tropical dry default values in the module**. This gives a value of **1 tC/ha/yr**.

Regarding the maximum AGC stock that restored mangroves can reach, the data in Alongi and Zimmerman, and the other papers indicate that **the IPCC Tier I value of 87 tC/ha is suitably**

conservative. All averaged datapoints in Alongi and Zimmerman for forest ages over 45 years are greater than the IPCC Tire I value and the average AGC stock in mangroves older than 45 years is 155 tC/ha. Bourgeois et al. report that average AGC stocks in intact mangrove forest is 99 tC/ha. It is proposed that **the same assumption is applied for the tropical dry climate zone**. Based on these maximum stock values, **restored mangroves in the tropical wet climate zone reach maturity at age 31 and restored mangroves in the tropical dry climate zone reach maturity at age 42.**

It is critical to note that all of these studies use data from restored, afforested or naturally regenerated sites. None of the papers detail the relative success of the restoration at each of the sites included in the meta-analyses. It is highly probable that some of the data used in these papers come from restoration areas that have some level of mortality. This may, in some way, lead to the variability in reported AGC stocks. Pathway One in the Simplified Mangrove Reforestation module accounts for such mortality separately, through the performance adjustment. Thus, using a AGC growth rate that is shaped by data from less successful restoration initiatives together with a project-specific performance adjustment adds an additional level of conservativeness to this approach.

The IPCC Tier I value for roots:shoots in the tropical wet climate zone is 0.49. The mean roots:shoots value across all datapoints in Alongi and Zimmerman is also 0.49, thus it is proposed that **the IPCC Tier I values for roots:shot continues to be used in the module** for both climate zones.

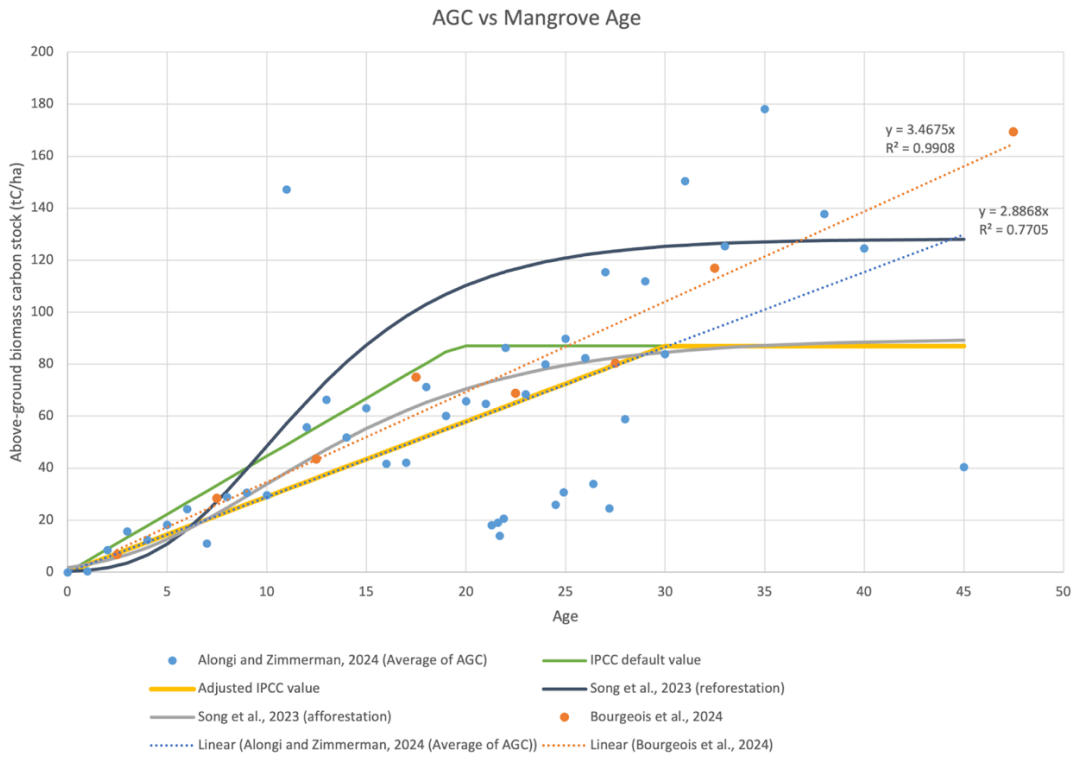


***Figure A1**. The proposed default value for AGC accumulation, calculated as 65% of the IPCC Tier I value, compared to original IPCC default value (green line), the linear trend in data published by Alongi and Zimmerman (blue dotted line) and Bourgeois et al., (orange dotted line) and the non-linear models presented by Song et al..*

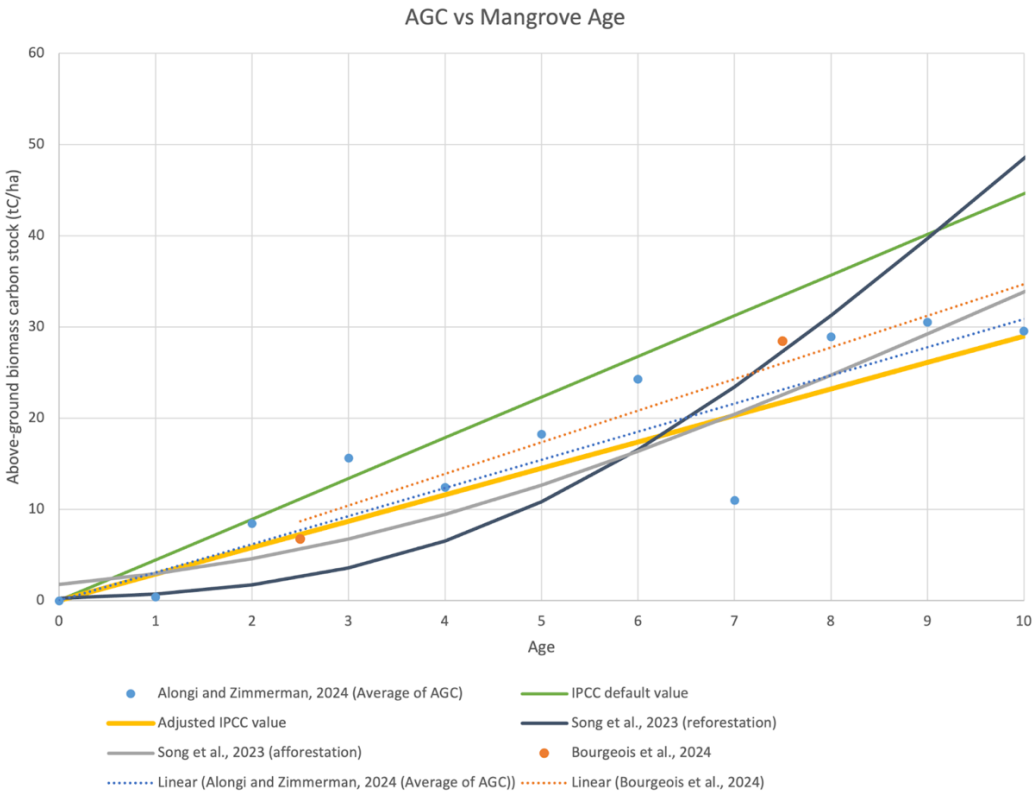


***Figure A2**. The same data presented in Figure A1, but only for forest ages 0-10 years.*

Research into soil organic carbon accumulation rates

As stated above, Alongi and Zimmerman look at soil carbon burial rates (SCBR) and how they vary depending on a range of factors, including forest age. They found that the relationship between SCBR and forest age was not significant, nor were there significant differences among species. Burial rates correlated only inversely with salinity and sediment C:N ratio. This suggests that a conservative, globally applicable, static rate of SOC accumulation is most appropriate given the lack of trends in the data.

SCBR in all reestablished mangrove stands ranged from 0.007 to 25.6 tC/ha/year, averaging 2.83 ± 3.26 tC/ha/year, with a median of 1.82 tC/ha/year.

Restricting the analysis to stands less than 50 years old leads to a mean SCBR of 2.7 tC/ha/year (all workings can be found in the 'CSR vs SOC stocks_PV' sheet). **Subtracting the 90% confidence interval from the mean gives a value of 2.18 tC/ha/year.**

There is considerable discourse regarding whether allochthonous carbon accumulation should be included in the estimated Climate Benefit of blue carbon projects. During the initial discussions with the Working Group that supported the development of this methodology, it was concluded that, whilst allochthonous carbon can form a significant proportion of the carbon buried in coastal sediments in both baseline and project scenarios, the quantification of this process is complicated and beyond the capacity of community-led carbon projects. Also, contributions vary significantly depending on local conditions, making appropriate default allochthonous deductions difficult to establish. One key driver of this conclusion was the lack of published data on the subject.

However, Zang et al., 2024 published a global-scale analysis of sediment autochthonous and allochthonous organic carbon contributions in estuarine and marine mangroves using stable isotopes. They found that mangrove-derived autochthonous organic carbon was the main contributor to estuarine and marine mangrove top-meter soil organic carbon (49% and 62%, respectively).

Such data opens up the possibility of explicitly adjusting the default SOC accumulation rate for the potential contribution of allochthonous carbon. To avoid projects needing to stratify project areas into marine and estuarine, which is potentially prohibitive for the community-led projects the module was designed for, it is proposed that **the more conservative estuarine value (49%) is used to adjust the 2.18 tC/ha/year value from Alongi and Zimmerman. This results in a revised default SOC accumulation rate of 1.1 tC/ha/year.**

Song et al. present non-linear models for increases in SOC stocks over time due to mangrove reforestation and afforestation. These models are based on SOC stocks, which are likely not zero at the start of reforestation. Figure A3 below shows the results of adjusting the non-linear trends to start at zero and compares them to the proposed default SOC accumulation rate. As can be seen, in all years the proposed default accumulation rate is more conservative than either of the non-linear trends from Song et al..

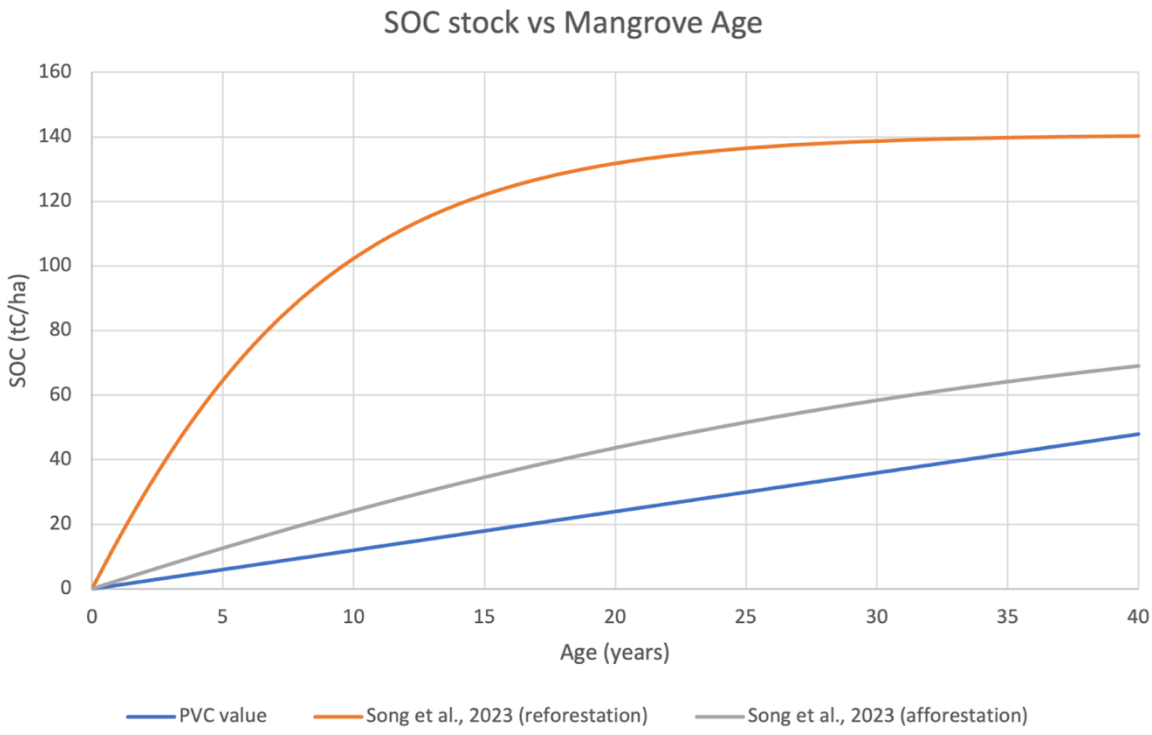
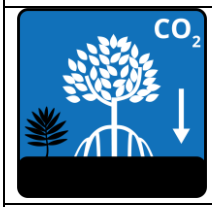
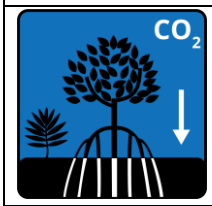
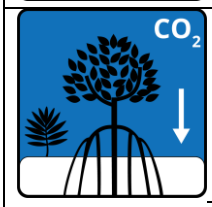
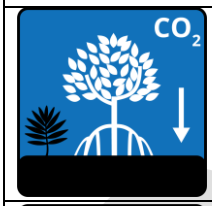
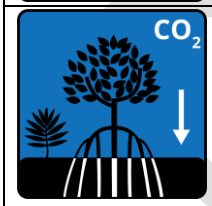
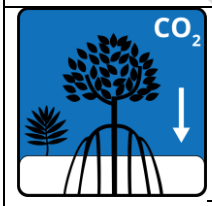


***Figure A3**. The proposed default value for SOC accumulation compared to the non-linear trends presented by Song et al..*

Proposed default values based on the propositions above

Tropical Wet IPCC climate zone		
Parameter	**Value**	**Time limit**
	**10.6** tCO_2e/ha/year *(2.9 tC/ha/year)*	Can only be applied for **30 years** from the start of restoration.
	**5.2** tCO_2e/ha/year *(1.42 tC/ha/year)*	
	**4.0** tCO_2e/ha/year *(1.1 tC/ha/year)*	No time limit. Can be applied in all years of the Crediting Period after the start of restoration.

Tropical Dry IPCC climate zone		
Parameter	**Value**	**Time limit**
	**3.7** tCO_2e/ha/year *(1 tC/ha/year)*	Can only be applied for **41 years** from the start of restoration.
	**1.1** tCO_2e/ha/year *(0.29 tC/ha/year)*	
	**4.0** tCO_2e/ha/year *(1.1 tC/ha/year)*	No time limit. Can be applied in all years of the Crediting Period after the start of restoration.