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All references to “ERS” refer to the standard body now operating under the Equitable Earth name.





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Contact:
Ecosystem Restoration Standard
25 Rue de Frémicourt
75015 Paris, FRANCE
info@ers.org

METHODOLOGY

Quantification Methodology for Reforestation

SUMMARY

This document details the methodological approach for quantifying GHG emission removals from reforestation activities. To guarantee conservative calculations and minimise the risk of perverse incentives, ERS is the entity responsible for performing these calculations, not the Developer.



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NORMATIVE REFERENCE


This document must be read in conjunction with:

- [M000](#)

READING NOTES

- Colour code:
 - Every element underlined in gold refers to an ERS template, guidelines or supporting document.
 - Every element *underlined in black italic* refers to another section of the Standard.
 - Every element underlined in green refers to a link external to ERS.
- Reading indications:

 These sections offer complementary insights into the Methodology, offering more in-depth information on future improvements or details on specific topics to facilitate comprehension.

 These sections provide examples to illustrate technical requirements of the Methodology.



DISCLAIMER

Due to ongoing research and development, the release of newer versions of ERS's methodologies, advancements in ERS's quantification methods, and the diverse range of v0.9 project contexts, some core elements of the [M000 Quantification Methodology](#) have since been updated or refined. To ensure the most accurate and conservative estimation of net GHG removals, ERS may apply updated quantification requirements to projects developed under v0.9, where appropriate. All updates to the quantification methods applied to each project will be detailed in the respective project's GHG monitoring report, publicly available on the ERS Registry. Projects certified under v0.9 may also choose to update to the latest version of the ERS Standard and methodology.



Boundaries

PROJECT BOUNDARIES

The physical boundaries relevant to this methodology are the Restoration Sites and the Reference Site. The physical boundaries delimit all the carbon pools, emission sinks, and emission sources considered in this quantification methodology.

EMISSION SINKS & SOURCES

1. List of Emission Sinks

Carbon pools included as emission sinks in the quantification methodology are listed below. Carbon pools are considered emission sinks if the Project absorbs GHG emissions from the atmosphere.

Carbon Pool	Type	Inclusion	Justification
Woody biomass	Aboveground	Yes	Significant carbon pool
	Belowground	Yes	Significant carbon pool
Non-woody biomass	Aboveground	Yes	Significant carbon pool
	Belowground	Yes	Significant carbon pool
Soil organic carbon (SOC)		No	Measurement uncertainties, conservative to exclude



Soil inorganic carbon (SIC)	No	Measurement uncertainties, conservative to exclude
Dead wood	No	Conservative to exclude
Litter	No	Conservative to exclude
Harvested wood products	No	Out of scope for this methodology

2. List of Emission Sources

Carbon pools included as emission sources in the quantification methodology are listed below. Carbon pools are considered emission sources in the event of reversals or leakage.

Carbon Pools	Type	Leakage	Reversal	Justification
Woody biomass	Aboveground	Yes	Yes	Significant carbon pool
	Belowground	Yes	Yes	Significant carbon pool
Non-woody biomass	Aboveground	Yes	Yes	Significant carbon pool
	Belowground	Yes	Yes	Significant carbon pool
Soil organic carbon (SOC)		No	No	Measurement uncertainties & out of scope for this methodology (soil inversion >25 cm not allowed)



Soil inorganic carbon (SIC)	No	No	Measurement uncertainties
Dead wood	No	N/A	Measurement uncertainties
Litter	No	N/A	Measurement uncertainties
Harvested Wood Products	No	N/A	Out of scope for this methodology (commercial harvesting not allowed)

Other emission sources that have been excluded from the quantification methodology, and the rationale for exclusion are listed below.

Emission sources	Justification
Burning of biomass	Out of scope for this methodology (not allowed)
Emissions from nitrogen fertilisers	Out of scope for this methodology (not allowed)
Burning of fossil fuels	<i>De minimis</i>

💡 Note that the only GHG covered in the scope of this methodology is carbon dioxide.



Carbon Stock *Quantification*

INITIAL CARBON STOCK

This step is used to estimate the initial baseline of the Restoration Site.

1. Land Cover Assessment

A land cover assessment is performed upon receipt of the Project shapefile. This assessment is performed to distinguish woody from non-woody areas within the Restoration Site.

💡 Remote sensing models quantifying AGB are solely trained on woody biomass and should not be used to estimate non-woody biomass. In order to assess GHG sequestration accurately, ERS separates woody from non-woody areas and uses different datasets to estimate them.

- 1.1. **Woody/Non-woody mask.** The Project shapefile is transferred to an AGB Provider to obtain a woody/non-woody biomass mask, a raster format map that distinguishes the location and size of woody areas within the Project Area. For precise information on the AGB Provider, refer to *Appendix 1*.
- 1.2. **Non-woody areas classification.** An analysis is performed to distinguish the different primary classes of the remaining non-woody areas (water, shrubs, grasses, bare soil, crops and buildings). The latest version of the ten metre ESA WorldCover model¹ is used to classify non-woody areas into specific land cover types (grasslands, shrublands, croplands, bare soils, built-up, and snow). This model

¹ At the time of publication, the 2021 v200 version. Zanaga, D., Van De Kerchove, R., Daems, D., De Keersmaecker, W., Brockmann, C., Kirches, G., Wevers, J., Cartus, O., et al. (2022). 'ESA WorldCover 10 m 2021 v200'. Available at: [URL](#) (Accessed 03/11/2023).



harnesses data from Sentinel-1 and Sentinel-2 satellites and employs machine-learning techniques to generate maps with a resolution of 10 metres.

2. Biomass Quantification of Woody and Non-Woody Areas

Separate approaches are then used to estimate AGB for Woody and Non-Woody land cover classes.

2.1. Above Ground Biomass.

2.1.1. **Woody areas.** The AGB Provider generates a Woody AGB map that estimates the AGB at the pixel level in raster format for woody areas. This is referred to as AGB_{rest}^w .

2.1.2. **Non-Woody areas.** Based on the information provided in the non-woody areas classification (1.2) various methods are employed to calculate non-woody AGB. Non-woody AGB is referred to as AGB_{rest}^{n-w} .

2.1.2.1. For shrubland a default ratio of 0.1 is used for conversion of forest biomass to shrubland biomass according to the AR-TOOL14².

2.1.2.2. For grasslands a default value for each climate zone is selected, according to the IPCC, as demonstrated in *Appendix 2*.

2.1.2.3. For bare soils and croplands, the AGB is estimated at 0.

2.1.2.4. Non-reforestable zones (infrastructure) are excluded from the AGB quantification.

² UNFCCC. (2013). 'AR-TOOL14 A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities Version 04.1'. Available at: [URL](#) (Accessed 25/01/2023)



2.2. Below Ground Biomass.

2.2.1. **Woody areas.** The woody BGB is estimated to be a proportion of its AGB as dictated by the root-to-shoot ratio (RS). The relationship between BGB and AGB is represented by the equation (1):

$$(1) \text{BGB}_{\text{rest}}^{\text{w}} = \text{AGB}_{\text{rest}}^{\text{w}} \times \text{RS}^{\text{w}}$$

Where:

- $\text{BGB}_{\text{rest}}^{\text{w}}$ = Woody BGB at the Restoration Site; tDM.
- $\text{AGB}_{\text{rest}}^{\text{w}}$ = Woody AGB at the Restoration Site; tDM.
- RS^{w} = Root-to-shoot ratio of woody biomass. A default value of 0.25 is adopted³; dimensionless.

2.2.2. **Non-woody areas.** For non-woody terrains, the estimation of BGB follows the same equation as for woody areas, guided by the IPCC's root-to-shoot ratio (RS)⁴, tailored to the specific climate zone. This approach ensures that the BGB estimation is reflective of the ecological and climatic characteristics of the region.

³ UNFCCC. (2013). 'AR-TOOL14 A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities Version 04.1'. Available at: [URL](#) (Accessed 25/01/2023)

⁴ Eggleston, H S, Buendia, L, Miwa, K, Ngara, T, and Tanabe, K. (2006) 'IPCC Guidelines for National Greenhouse Gas Inventories. Japan.' Volume 4, Chapter 6, Table 6.4, p 6.27. Available at: [URL](#) (Accessed 03/11/2023).



Non-woody BGB is calculated using equation (2):

$$(2) \text{BGB}_{\text{rest}}^{\text{n-w}} = \text{AGB}_{\text{rest}}^{\text{n-w}} \times \text{RS}^{\text{n-w}}$$

Where:

- $\text{BGB}_{\text{rest}}^{\text{n-w}}$ = Non-woody BGB at the Restoration Site; tDM.
- $\text{AGB}_{\text{rest}}^{\text{n-w}}$ = Non-woody AGB at the Restoration Site; tDM.
- $\text{RS}^{\text{n-w}}$ = Root-to-shoot ratio of non-woody biomass. A default value is obtained from the IPCC for each climate zone or from AR-TOOL14; dimensionless.

2.2.3. The aggregated biomass (AGB and BGB) is also provided by the IPCC and is outlined in [Appendix 2](#).

3. Total Biomass of the Restoration Site

The aggregated biomass is composed of the above and below ground biomass of the woody and non-woody components in the Restoration Site. To quantify this, equations (3), (4) and (5) are used:

$$(3) \text{B}_{\text{rest}}^{\text{w}} = \text{AGB}_{\text{rest}}^{\text{w}} + \text{BGB}_{\text{rest}}^{\text{w}}$$

Where:

- $\text{B}_{\text{rest}}^{\text{w}}$ = Total woody biomass at the Restoration Site; tDM.
- $\text{AGB}_{\text{rest}}^{\text{w}}$ = Woody AGB at the Restoration Site; tDM.
- $\text{BGB}_{\text{rest}}^{\text{w}}$ = Woody BGB at the Restoration Site; tDM.



$$(4) \mathbf{B}_{rest}^{n-w} = \mathbf{AGB}_{rest}^{n-w} + \mathbf{BGB}_{rest}^{n-w}$$

Where:

- \mathbf{B}_{rest}^{n-w} = Total non-woody biomass at the Restoration Site; tDM.
- $\mathbf{AGB}_{rest}^{n-w}$ = Non-woody AGB at the Restoration Site; tDM.
- $\mathbf{BGB}_{rest}^{n-w}$ = Non-woody BGB at the Restoration Site; tDM.

$$(5) \mathbf{B}_{rest} = \mathbf{B}_{rest}^w + \mathbf{B}_{rest}^{n-w}$$

Where:

- \mathbf{B}_{rest} = Total biomass at the Restoration Site; tDM.
- \mathbf{B}_{rest}^w = Total woody biomass at the Restoration Site; tDM.
- \mathbf{B}_{rest}^{n-w} = Total non-woody biomass at the Restoration Site; tDM.

4. Biomass Conversion to CO2 Equivalents

Biomass in the Restoration Site is converted into CO2 equivalents (CO2e) to determine its total CO2 sequestration.



The AR-TOOL14 A/R Methodological tool's equations⁵ are used to translate biomass into carbon content and subsequently into CO₂e. This ensures a consistent and standardised measurement aligned with global carbon reporting metrics.

The relation between carbon stock and tree biomass can be established with equation (6).

$$(6) \mathbf{C}_{rest} = \frac{44}{12} \times \mathbf{CF} \times \mathbf{B}_{rest}$$

Where:

- \mathbf{C}_{rest} = Carbon stock in the Restoration Area; tCO₂e.
- $\frac{44}{12}$ = Represents the molecular weight ratio of CO₂ to Carbon, which is $\frac{44}{12}$; dimensionless.
- \mathbf{CF} = Carbon fraction of tree biomass; tC:tDM⁻¹.
A default value of 0.47 is adopted⁶.
- \mathbf{B}_{rest} = Total biomass at the Restoration Site; tDM.

This initial baseline is determined by the carbon stock (\mathbf{C}_{rest}) and is expressed in tonnes of CO₂e.

FINAL CARBON STOCK

This step estimates the carbon stock of the Reference Site.

1. Selection of a Reference Ecosystem

- 1.1. ERS requests the selection and adoption of a Reference Ecosystem and geographical coordinates of a physical Reference Site.

⁵ UNFCCC. (2013). 'AR-TOOL14 A/R Methodological tool: Estimation of carbon stocks and change in carbon stocks of trees and shrubs in A/R CDM project activities Version 04.1'. Available at: [URL](#) (Accessed 25/01/2023)

⁶ Eggleston, H S, Buendia, L, Miwa, K, Ngara, T, and Tanabe, K. (2006) 'IPCC Guidelines for National Greenhouse Gas Inventories. Japan.' Volume 4, Chapter 4, Table 4.3, p 4.48. Available at: [URL](#) (Accessed 03/11/2023).



- 1.2. The Project's Reference Ecosystem is used to inform the restoration objectives.
- 1.3. The Reference Site is used to quantify the carbon sequestration potential of the Project.

2. Carbon Stock at Reference Site

- 2.1. Upon submission of the Reference Site's shapefile, the AGB provider generates:
 - 2.1.1. **A woody/non-woody biomass mask** in raster format, showing the distinction between woody and non-woody areas at the Reference Site.
 - 2.1.2. **A woody AGB map** that estimates the AGB at the pixel level in raster format.
- 2.2. Woody BGB is estimated using AGB values from step 2.1.2, following equation (7):

$$(7) \mathbf{BGB}_{\text{ref}}^{\text{w}} = \mathbf{AGB}_{\text{ref}}^{\text{w}} \times \mathbf{RS}^{\text{w}}$$

Where:

- $\mathbf{BGB}_{\text{ref}}^{\text{w}}$ = Woody BGB in the Reference site; tDM.
- $\mathbf{AGB}_{\text{ref}}^{\text{w}}$ = Woody AGB in the Reference site; tDM.
- \mathbf{RS}^{w} = Root-to-shoot ratio, a default value of 0.25 is adopted; dimensionless.

- 2.3. The total biomass of the Reference Site is calculated using equation (8):

$$(8) \mathbf{B}_{\text{ref}} = \mathbf{AGB}_{\text{ref}}^{\text{w}} + \mathbf{BGB}_{\text{ref}}^{\text{w}}$$



Where:

- B_{ref} = Total woody biomass at the Reference Site; tDM.
- AGB_{ref}^w = Woody AGB in the Reference Site; tDM.
- BGB_{ref}^w = Woody BGB in the Reference Site; tDM.

2.4. The conversion to CO₂e is obtained using formula (9):

$$(9) C_{ref} = \frac{44}{12} \times CF \times B_{ref}$$

Where:

- C_{ref} = Carbon stock on the Reference Site; tCO₂e.
- $\frac{44}{12}$ = Represents the molecular weight ratio of CO₂ to Carbon, which is $\frac{44}{12}$; dimensionless.
- CF = Carbon fraction of tree biomass; tC·tDM⁻¹.
A default value of 0.47 is used.
- B_{ref} = Total woody biomass at the Reference Site; tDM.

2.5. The average carbon sequestration in the Reference Site is calculated as an estimate of the carbon sequestration by size (in hectares). This process enables the utilisation of this data for further processing in the calculation of the carbon sequestration potential of the Project. To calculate the average carbon sequestration per hectare in the Reference Site, equation (10) is followed:

$$(10) \overline{C}_{ref} = C_{ref} / A_{ref}$$



Where:

- \overline{C}_{ref} = Mean carbon stock on the Reference Site, represents the mean CO₂ sequestered; tCO₂e·ha⁻¹.
- C_{ref} = Carbon stock on the Reference Site; tCO₂e.
- A_{ref} = Area of the Reference Site; ha.

CARBON SEQUESTRATION POTENTIAL

Using the initial and final carbon stocks, this step estimates the carbon sequestration potential of the Restoration Sites.

💡 In this methodology, ERS assumes that Restoration Sites will achieve levels of carbon sequestration similar to the Reference Site by the end of the crediting period.

1. Carbon Sequestration Potential of Restoration Sites

- 1.1. The carbon sequestration potential is defined as the GHG emission removal capacity of the Project.
- 1.2. The initial baseline and the mean carbon stock of the Reference Site are evaluated to determine the Project's GHG emission removal capacity.
- 1.3. The carbon sequestration potential of a restoration Project is determined by calculating the difference between the projected carbon sequestration of the Restoration Site and the current carbon sequestration in the Restoration Site. This is represented by equation (11):



$$(11) C_{\text{potential}} = (A_{\text{project}} \times \overline{C_{\text{ref}}}) - C_{\text{rest}}$$

Where:

- $C_{\text{potential}}$ = Represents the Project's carbon sequestration potential; tCO₂e.
- A_{project} = Represent the size of the Restoration Site; ha.
- $\overline{C_{\text{ref}}}$ = Mean carbon stock on the Reference Site, represents the mean CO₂ sequestered; tCO₂e·ha⁻¹.
- C_{rest} = Represents the initial carbon stock of the Restoration Sites; tCO₂e.



Carbon Stock *Accounting*

PRU ACCOUNTING

Total PRUs are calculated following this given formula:

$$(12) \text{ PRU} = C_{\text{potential}}$$

Where:

- **PRU** = Project Restoration Units; tCO₂e.
- **C_{potential}** = Represents the Project's carbon sequestration potential; tCO₂e.

VRU ACCOUNTING

PRUs conversion into VRUs is performed every two years after Verification, and throughout the Project's crediting period. Prior to each Verification and so as to ensure the most accurate conversion of units, ERS measures carbon stock in the Restoration Sites, factoring:

1. **Biomass evolution in the Restoration Site.** The evolution of the CO₂ sequestration at the Restoration Site is calculated by comparing the biomass status at verification cycle t , with the biomass status at verification cycle $t-1$. It is important to note that this evaluation includes any reversals that occurred on the Restoration Site during verification cycle t .

Total VRUs for the verification cycle t are calculated following this given formula:

$$(13) \text{ VRU}_t = \Delta C_t^{\text{conservative}}$$



Where:

- \mathbf{VRU}_t = Verified Restoration Unit for the verification cycle t ; tCO₂e.
- $\Delta\mathbf{C}_t^{\text{conservative}}$ = Net conservative GHG benefits achieved during the verification cycle t ; tCO₂e.



Uncertainty & *Conservativeness*

This section described how ERS accounts for uncertainty in its quantification methods, and the rules enforced to ensure conservative carbon estimations.

UNCERTAINTY

1. Woody AGB Estimation

AGB estimation is not a direct measurement; it is therefore inherently uncertain. Managing this uncertainty effectively is critical for the credible quantification of tCO_{2e} removals from restoration activities. To minimise and account for uncertainty related to AGB estimation, ERS implements best practices outlined in the Aboveground Woody Biomass Product Validation Good Practices Protocol⁷. This means that:

- 1.1. AGB error estimation must consider the entire process, from field measurements to modelling errors, including those associated with allometric equations.
- 1.2. The propagation of uncertainty through these various stages must be effectively managed.
 - 1.2.1. ERS's AGB benchmark (*Appendix 1*) demonstrates different methods of AGB uncertainty propagation.
- 1.3. A 95% confidence interval for AGB values must be generated.

⁷ Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., MacBean, N., McRoberts, R., Minor, D., Paul, K., Réjou-Méchain, M., Roxburgh, S., Williams, M., Albinet, C., Baker, T., Bartholomeus, H., Bastin, J.F., Coomes, D., Crowther, T., Davies, S., de Bruin, S., De Kauwe, M., Domke, G., Dubayah, R., Falkowski, M., Fatoyinbo, L., Goetz, S., Jantz, P., Jonckheere, I., Jucker, T., Kay, H., Kellner, J., Labriere, N., Lucas, R., Mitchard, E., Morsdorf, F., Naeset, E., Park, T., Phillips, O.L., Ploton, P., Puliti, S., Quegan, S., Saatchi, S., Schaaf, C., Schepaschenko, D., Scipal, K., Stovall, A., Thiel, C., Wulder, M.A., Camacho, F., Nickeson, J., Román, M., Margolis, H. (2021). Aboveground Woody Biomass Product Validation Good Practices Protocol. Version 1.0. In L. Duncanson, M. Disney, J. Armston, J. Nickeson, D. Minor, and F. Camacho (Eds.), *Good Practices for Satellite Derived Land Product Validation*, (p. 236): Land Product Validation Subgroup (WGCV/CEOS), Available at: [URL](#).



2. Current AGB Model Uncertainty

- 2.1. Baccini et al. 2017⁸ describe in detail the [Chloris'](#) stock and change product, which explains that the model employed includes for every pixel an estimate of:
 - 2.1.1. total change over the time series (i.e., gain or loss) calculated as the difference between the fitted values at the beginning and end points of the pixel-level trajectories;
 - 2.1.2. the p-value (scaled 0-100) from a modified F-test associated with the pixel-level change estimate where p-values ≤ 5 represent a significant change (i.e., gain or loss) in Aboveground Biomass Density (AGBD) and values > 5 represent a non-significant change (i.e., no gain or loss/stable) in AGBD;
 - 2.1.3. and the standard error associated with the pixel-level change representing uncertainty in the change estimate at the 95% level. The uncertainty associated with the pixel-level estimates of AGBD change can be obtained from the map of standard error.
 - The standard error is estimated from an error propagation analysis carried out at the pixel level across all layers in the time series. The propagation of error, which takes into account geolocation-, allometric-, and model-based errors, feeds first into estimates of the standard error associated with the AGBD prediction at each point in the time series understood most readily as the confidence interval (C.I.) for each pixel-level trajectory. This C.I. envelope is then used to calculate the standard error of the AGBD change. All AGBD change statistics reported are derived from sums of pixel values where the change (i.e.,

⁸ Baccini, A., Walker, W., Carvalho, L., Farina, M., Sulla-Menashe, D. and Houghton, R.A. (2017). 'Tropical forests are a net carbon source based on aboveground measurements of gain and loss'. *Science*, 358(6360), pp.230-234. Available at: [URL](#) (Accessed 3/11/2023)



gain or loss) was determined to be significant (p -value ≤ 5).

- The standard error pixel-level estimates are aggregated to the site level in a process that takes into account the spatial autocorrelation and is used to compute the overall site level uncertainty for the AGBD and change.

CONSERVATIVENESS

ERS adopts a conservative approach when quantifying the GHG emission removals of a Project. This approach is executed in two layers:

1. Evaluating Uncertainty in Estimates

Uncertainty is calculated holistically throughout the quantification process, from field measurements to model outputs. The uncertainty estimation is detailed in the "Aboveground Woody Biomass Product Validation Good Practices Protocol." A more granular exposition on the uncertainty calculation methodology is described in the *Current AGB Model Uncertainty* section.

2. Maximised Conservatism

The conservative approach consistently and systematically selects the uncertainty boundary that leans towards the safe side. This prevents any potential overestimation of GHG emission removals. The calculation takes on different forms to deliberately apply conservativeness at each step of the quantification process. The following sections include details about the conservative approach at each step.

2.1. CO₂ Sequestration Potential

- 2.1.1. **Initial Carbon Stock.** When quantifying the initial baseline, the upper band of the 95% confidence interval is selected for Woody AGB values. Confidence intervals are provided by the AGB provider. Such selection allows for an overestimation of the current state of the Restoration Site. This selection will implicitly



provide a conservative estimate of the carbon sequestration potential of the Project.

2.1.2. **Final Carbon Stock.** When quantifying carbon stock in the Reference Ecosystem, the lower band of the 95% confidence interval is chosen. This leads to an underestimation of the current sequestration of the Reference Ecosystem. This selection will implicitly provide a conservative estimate of the carbon sequestration potential of the Project.

2.1.3. **Carbon Sequestration Potential.** Having applied a conservative approach in the quantification of the initial baseline scenario at the Project Area, and a conservative quantification of CO₂ sequestration at the Reference Site, the GHG emission removal potential which results from the difference between the two, is implicitly conservative.

2.2. **Monitoring.**

2.2.1. While measuring the carbon sequestration of the Project Area every two years, the lower band of the 95% confidence interval is selected. This results in an underestimation of the current sequestration on the Restoration Site.

2.3. **Loss Events**

2.3.1. During the impact assessment of reversals, an inherent challenge is determining the BGB loss through satellite imagery. ERS conservatively considers a complete loss of BGB and deducts the CO₂e stock bound to BGB from the Project issuances.



Appendix 1 – *AGB Provider*

BENCHMARK PROCESS

The selection of an accurate AGB provider is instrumental in ensuring precise carbon estimation. A benchmarking approach was employed to identify the most suitable AGB provider for ERS. The process overview is described below, for more detailed information refer to the [AGB Benchmark](#).

1. Initial Provider Contact

Multiple AGB providers were approached to participate in the benchmarking process. Each received a shapefile document with geographic information of a forested area, to apply their AGB models and determine their values.

2. Model Output Comparison

We employ the AGB model outputs from each provider to gather essential statistical information. This information is compared among the various providers. Furthermore, a detailed comparison is conducted in certain sub-areas of the model against a designated reference model.

3. Selection Criteria

- 3.1. **Precision.** The accuracy of the AGB model in predicting biomass values.
- 3.2. **Uncertainty Analysis.** The methodology for calculating uncertainty and how it is propagated from field measurements all the way to the final AGB model.
- 3.3. **Coverage.** The extent of the area that the model could cover and its flexibility in application.
- 3.4. **Integration Feasibility.** The ease and efficiency of integrating the model into the ERS certification process.



4. Conclusion

Based on the criteria, the most appropriate AGB provider was selected to ensure rigorous, conservative and accurate data is integrated in this quantification methodology. For this version of the methodology, [Chloris Geospatial](#) has been selected as the AGB provider.

5. Iteration

The benchmark process can be repeated at any time, and at least every two years, following [Standard Revision Procedure](#). ERS seeks to use data providers that apply the principles and rigour described in this methodology, as such, an updated benchmark process allows ERS to ensure the proper selection of its AGB provider.

Undertaking a repeated benchmark process in the future can result in changing the AGB provider. Shall ERS take this decision, it will be openly communicated in its methodology documents.



Appendix 2 – *IPCC Data*

ERS selects IPCC⁹ default values by climate zone for above and below-ground biomass in grasslands, as described in the table 6.4. and shown below:

IPCC climate zone	Peak above-ground biomass¹ (tonnes d.m. ha⁻¹)	Total (above-ground and below-ground) non-woody biomass² (tonnes d.m. ha⁻¹)	Error ³
Boreal – Dry & Wet ⁴	1.7	8.5	± 75%
Cold Temperate – Dry	1.7	6.5	± 75%
Cold Temperate –Wet	2.4	12	± 75%
Warm Temperate – Dry	1.6	6.1	± 75%
Warm Temperate –Wet	2.7	13.5	± 75%
Tropical – Dry	2.3	8.7	± 75%
Tropical - Moist & Wet	6.2	16.1	± 75%

¹ Data for standing biomass are compiled from multi-year averages reported at grassland sites registered in the ORNL DAAC NPP database [<http://www.daacsti.ornl.gov/NPP/>].

² Total above-ground and below-ground biomass values are based on the peak above-ground biomass values, and the below-ground biomass to aboveground biomass ratios (Table 6.1).

³ Represents a nominal estimate of error, equivalent to two times standard deviation, as a percentage of the mean.

⁴ Due to limited data, dry and moist zones for the boreal temperature regime and moist and wet zones for the tropical temperature regime were combined.

⁹ Eggleston, H S, Buendia, L, Miwa, K, Ngara, T, and Tanabe, K. (2006) 'IPCC Guidelines for National Greenhouse Gas Inventories. Japan.' Volume 4, Chapter 6, Table 6.4, p 6.27. Available at: [URL](#) (Accessed 03/11/2023).



Appendix 3 – *Document History*

Version	Date	Comment
0.9	01/03/2022	Public release of version 0.9 of the <i>M000 – Quantification Methodology for Reforestation</i>
0.9	08/07/2025	Inclusion of a disclaimer section (p. 2) to address updates to quantification methods for v0.9 projects.



Ecosystem Restoration Standard

info@ers.org | www.ers.org