FRAMEWORK FOR

REMOTELY SENSED QUANTIFICATION OF FOREST CARBON

VERSION 1.0

March 2026

ACR AT WINROCK INTERNATIONAL

FRAMEWORK FOR

REMOTELY SENSED QUANTIFICATION OF FOREST CARBON

VERSION 1.0

March 2026

ACR℠

OFFICE ADDRESS
Environmental Resources Trust, LLC
325 W Capitol Ave, Suite 350
Little Rock, Arkansas 72201 USA
ph +1 571 402 4235

ACR@winrock.org
acrcarbon.org

ABOUT ACR℠

ACR is a leading global carbon crediting program operating in regulated and voluntary carbon markets. Founded in 1996 as the first private voluntary greenhouse gas (GHG) registry in the world, ACR creates confidence in the integrity of carbon markets to catalyze transformational climate results. ACR ensures carbon credit quality through the development of environmentally rigorous, science-based standards and methodologies as well as oversight of GHG project verification, registration, and credit issuance and retirement reporting through its transparent registry system. ACR is governed by Environmental Resources Trust LLC, a wholly-owned nonprofit subsidiary of Winrock International.

Acknowledgements

ACR would like to thank GreenTrees for the technical expertise provided in support of this Framework. Financial support for the development of this Framework was provided by the Weyerhaeuser Giving Fund. Chloris Geospatial provided remote sensing data that was helpful in testing proof of concept.

Acronyms

AOI	Area of Interest
CO_2e	Carbon dioxide equivalent
ERR	Emission reductions and/or removals
GHG	Greenhouse gas
GIS	Geographic information system
IFM	Improved forest management
IPCC	Intergovernmental Panel on Climate Change
LiDAR	Light Detection and Ranging
LULUCF	Land Use, Land Use Change and Forestry
QA/QC	Quality assurance/ quality control
RADAR	Radio Detection and Ranging
RMSE	Root mean squared error
SOP	Standard operating procedures
VVB	Validation/Verification Body

Contents

ACKNOWLEDGEMENTS **3**

ACRONYMS **4**

CONTENTS **5**

1 INTRODUCTION **7**

1.1 SUMMARY 7

1.2 APPLICABILITY 7

1.3 APPLICATION IN GHG PROJECTS 8

1.3.1 BASELINE DEVELOPMENT 8

1.3.2 FRAMEWORK OUTPUTS 9

1.4 SPATIAL SCOPE (AREA OF INTEREST) 9

1.5 TEMPORAL SCOPE 10

1.5.1 APPLYING THIS FRAMEWORK IN CONJUNCTION WITH A GROUND-BASED INVENTORY 11

1.5.2 DEFINING THE PREDICTED TIME 11

1.6 POOLS AND SOURCES 11

1.7 PROCESS 12

2 PREDICTIVE MODELS **15**

2.1 PREDICTIVE MODEL REQUIREMENTS 15

2.2 PREDICTIVE MODEL DESIGN 16

2.3 CALIBRATION PLOTS 16

2.4 MEAN CARBON DENSITY 17

3 ASSESSING MODEL ELIGIBILITY WITH VALIDATION PLOTS **19**

3.1 VALIDATION PLOT LOCATION GENERATION 19

3.2 VALIDATION PLOT INSTALLATION AND MEASUREMENT 20

3.3 ASSESSING PREDICTIVE MODEL ELIGIBILITY 21

3.4 STATISTICAL AGREEMENT AND DISCONTINUATION 24

4 VALIDATION PLOT REMEASUREMENT **26**

4.1 MODEL APPROVAL 27

5 CALCULATION AND REPORTING OF CARBON STOCKS 28
5.1 ABOVEGROUND CARBON STOCKS 28
5.2 BELOWGROUND CARBON STOCKS 28
5.3 PROJECT-LEVEL CARBON STOCKS 29
5.4 PROJECT-LEVEL UNCERTAINTY 30
6 REPORTING AND VERIFICATION 32
6.1 REPORTING 32
6.2 VALIDATION AND VERIFICATION 36
DEFINITIONS 38
APPENDIX A: REFERENCES 39

FIGURES

Figure 1: Steps for Developing, Assessing, and Approving the Use of Remote Sensing Data to Quantify Forest Carbon 13
Figure 2: Example timeline of Framework approval process for a GHG Project. 14

EQUATIONS

Equation 1: AOI-Level Mean Carbon Density 18
Equation 2: Area-weighted Average Carbon Density 22
Equation 3: Root Mean Squared Error 22
Equation 4: Uncertainty Percentage using Root Mean Squared Error 23
Equation 5: 90% Confidence Interval 23
Equation 6: Uncertainty Percentage at 90% Confidence Interval 24
Equation 7: Minimum Remeasured Validation Plot Count 26
Equation 8: AOI-Level Aboveground Carbon Stocks 28
Equation 9: AOI-Level Above- and Belowground Carbon Stocks 29
Equation 10: Project-level Carbon Stocks 30
Equation 11: Project-level Uncertainty 31

1 Introduction

1.1 Summary

This *ACR Framework for Remotely Sensed Quantification of Forest Carbon* (henceforth, the Framework) prescribes quantification standards, validation guidelines and steps for employing Predictive Models based on Remote Sensing of carbon pools in ACR forest GHG projects (Figure 1).

The Framework establishes statistical thresholds for accuracy and uncertainty of a Predictive Model's carbon stock estimates. The Project Proponent must measure randomly allocated ground-based forest inventory plots (i.e., Validation Plots). The carbon stock estimates derived from the Validation Plots are statistically compared against the Predictive Model carbon stock estimates. If all thresholds are met, a Predictive Model is deemed eligible to utilize the model's carbon stock estimates in project quantification and reporting of the forest GHG project.

The Framework also establishes a procedure for Validation/Verification Bodies (VVB) to confirm the accurate measurement of a Project Proponent's Validation Plots via independent remeasurement results of a statistical test. Once a VVB's remeasurements have confirmed the Project Proponent's accurate measurement of Validation Plots, the Predictive Model is approved to estimate carbon stocks in the GHG project.

Predictive Models may use any Remote Sensing technology and carbon stock's predictive modeling approach, so long as it meets the established thresholds. Auxiliary data not based on Remote Sensing (e.g., soil or topographic data) may be used to develop a Predictive Models. "Off the shelf" commercially available data products may also be used as a Predictive Model.

Use of this Framework must coincide with a GHG project's validation and/or a full verification that includes a site visit to the GHG project area. Once approved for use, a Predictive Model is valid for 5 years of reporting, at which point the same or an updated Predictive Model must be submitted for approval for use. Other Methodology-approved approaches (e.g., a Ground Plot-based forest inventory) may be applied to derive carbon stocks at any time, including during the 5-year period.

1.2 Applicability

This Framework is applicable to the following ACR Methodologies:

- *Afforestation and Reforestation of Degraded Lands*
- *Active Conservation and Sustainable Management on U.S. Forestlands*

- *Improved Forest Management on Canadian Forestlands*
- *Improved Forest Management on Non-Federal U.S. Forestlands*

This Framework does not supersede any of the requirements of specific Methodologies. Rather, this Framework addresses how a Predictive Model and its resulting outputs can be evaluated and applied within a given Methodology's existing accounting framework.

1.3 Application in GHG Projects

Given the range of applicable Methodologies and their unique requirements, the methods to apply this Framework will vary by Methodology.

The following Methodologies require ground-based (e.g., tree-level or stand-level) inventories to apply growth models to develop baselines and calculate harvested wood products at project Validation:

- *Active Conservation and Sustainable Management on U.S. Forestlands*
- *Improved Forest Management on Canadian Forestlands*
- *Improved Forest Management on Non-Federal U.S. Forestlands*

Projects applying these Methodologies may not apply this Framework to derive initial carbon stocks (i.e., stocks at time 0; see Section 1.5.1 for further details). These projects may begin to apply the Framework to estimate with-project carbon stocks at any point thereafter.

The following Methodology does not require a ground-based inventory to develop baselines if using this Framework, and therefore projects applying this Methodology may apply the Framework to estimate carbon stocks at any point:

- *Afforestation and Reforestation of Degraded Lands*

1.3.1 BASELINE DEVELOPMENT

ACR forest carbon Methodologies have varying methods for establishing estimates of baseline emissions reductions and removals.

Projects applying Methodologies that require ground-based inventories to utilize growth models for baseline development (i.e., *Active Conservation and Sustainable Management on U.S. Forestlands* and IFM methodologies) must use methods prescribed by the applied Methodology and validation scope (e.g., field measurements, model selection and calibration for site-specific conditions and tree growth) to derive initial carbon stock estimates. There is no interaction between this Framework and baseline Validation for these Methodologies.

Projects applying the *Afforestation and Reforestation of Degraded Lands* Methodology may use this Framework to quantify initial carbon stocks in both the with-project and baseline scenarios (i.e., the initial carbon stocks for both scenarios must be equal). if this framework is chosen, they may use this Framework to develop initial carbon stock estimates that inform baseline development.

GHG projects that have previously validated baselines for all applicable Methodologies may utilize this Framework to quantify with-project carbon stocks on a forward-moving basis (i.e., in subsequent Reporting Periods following model approval).

1.3.2 FRAMEWORK OUTPUTS

The outputs resulting from the application of this Framework, which are used in project accounting to calculate Total GHG Emission Reductions and Removals and uncertainty deductions (where applicable) per the applied Methodology, are:

- Project-level carbon stocks in the with-project scenario for a Reporting Period.
  - GHG projects applying this Framework to the *Afforestation and Reforestation of Degraded Lands* Methodology will derive initial carbon stocks estimates for both the with-project and baseline scenarios (i.e., the initial carbon stocks).
- Project-level uncertainty for with-project and baseline (when applicable) carbon stock estimates derived from the Framework.

1.4 Spatial Scope (Area of Interest)

When applying this Framework, the Project Proponent must define the Predictive Model's spatial scope (i.e., its Area of Interest or AOI). Each Predictive Model must be associated with a single defined AOI.

An AOI may contain either the entire GHG project area or only a part of it. Therefore, a GHG project area may include one or more Areas of Interest (hereafter, AOIs). If a GHG project area includes multiple AOIs, the Project Proponent must seek approval for each AOI's Predictive Model independently. Any parts of the GHG project area that are not included in a Predictive Model's AOI must use another Methodology-approved inventory (e.g., a Ground Plot-based forest inventory) to estimate that area's carbon stocks. If the GHG project area includes more than one AOI, or if it includes areas that are not included in an AOI, the instructions in Section 5.3 must be applied to combine the multiple carbon stock estimates into a single project-level estimate.

1.5 Temporal Scope

Use of this Framework must coincide with a GHG project's validation and/or a full verification including a site visit to the project site. Once approved for use, a Predictive Model is valid for 5 years of reporting, calculated from the start date of the Reporting Period receiving full verification (Figure 2).

- The Predictive Model may be used to calculate and report carbon stocks at different points in time during this 5-year period. When doing so, the Predictive Model may not be further calibrated from its originally approved state (i.e., the Predictive Model may not change during its 5-year approval period without repeating the entirety of this Framework including installation of new Validation Plots and revalidation of the Predictive Model). However, newly collected Remote Sensing measurements or other input data sources representing different points in time may be processed by the approved model, creating new Pixel-level outputs. These new outputs are used in the calculation of carbon stocks (Equations 1, 8, 9 and 10) while skipping all steps regarding Validation Plots and AOI-level uncertainty (Sections 3 and 4).
- AOI-level uncertainties (Equation 3) shall remain fixed throughout the 5-year period. Project-level uncertainty (Equation 11) shall remain fixed unless the uncertainty associated with carbon stocks for areas not included in an AOI changes (e.g., when coupling a remotely sensed AOI with a field-measured AOI).

After this 5-year period, the previously approved Predictive Model is no longer approved for use. To continue to use a Predictive Model to estimate carbon stocks for project reporting, this Framework (including installation of new Validation Plots resulting in new carbon stock and uncertainty estimates) must be reapplied coincident with a full verification. In the absence of a subsequent successful application of this Framework, a Project Proponent must revert to carbon stock and uncertainty calculations using a Methodology-approved inventory approach (e.g., a Ground Plot-based forest inventory).

After a Predictive Model is approved for use, there is no requirement to use it to derive annual or interim carbon estimates within its 5-year period. Other Methodology approved approaches, such as growth modeling, may be used to derive with-project carbon stocks in such increments.

This Framework may be employed again to approve a different Predictive Model before a previously approved Predictive Model's 5-year period expires. However, only one valid Predictive Model can be approved per AOI at any given point in time. Other Methodology-approved approaches (e.g., a Ground Plot-based forest inventory) may be applied to derive carbon stocks at any time, including during the 5-year period.

1.5.1 APPLYING THIS FRAMEWORK IN CONJUNCTION WITH A GROUND-BASED INVENTORY

As noted in Section 1.3, certain Methodologies (e.g., *Improved Forest Management on Canadian Forestlands*) require ground-based inventories to derive initial carbon stocks for baseline development. Since this Framework must be applied coincident with a validation and/or a full verification including a site visit to the project site, a GHG project deriving initial carbon stocks at validation may choose to apply this Framework despite not employing the resulting carbon stock estimates and uncertainty from the Predictive Model at time 0 in project accounting. This approach would enable the project to utilize the approved Predictive Model to estimate carbon stocks and uncertainty for a 5-year approval period starting from the project Start Date, including the end date of the first Reporting Period. When applying this Framework without reporting the resulting carbon stocks and uncertainty in project accounting, all the reporting, verification, and processes of this Framework still apply.

The outputs of this Framework are not to be used in conjunction with methodology approved growth and yield models during desk verifications for estimating with-project carbon stocks. Rather, they are to be used as the direct basis for estimating with-project carbon stocks.

1.5.2 DEFINING THE PREDICTED TIME

Each time this Framework is used to report carbon stocks for a GHG project, Project Proponents must define the specific date for which the Predictive Model is estimating carbon stocks. This definition process must be systematic, repeatable, and based on Remote Sensing measurements or other input data sources. The GHG Project's Reporting Period end date must align with the Predictive Model's defined date.

If an approved Predictive Model is used to calculate and report carbon stocks at later points in time within its 5-year approval period, the originally applied process for defining the predicted time must be replicated using newly collected input data sources (if available).

1.6 Pools and Sources

At minimum, Predictive Models must estimate carbon stocks for the aboveground live biomass carbon pool. If a GHG project also includes aboveground standing dead wood, the Predictive Model must also estimate this pool, and this Framework cannot be used to estimate carbon stocks in one of these pools without the other.

Predictive Models may not estimate belowground carbon stocks for either live biomass or standing dead wood. GHG projects employing this Framework must calculate belowground biomass according to Section 5.2.

Predictive Models may not be used to estimate any other pools or sources (e.g., harvested wood products) included in the GHG project. Project Proponents must apply Methodology instructions for quantifying other included pools and sources.

1.7 Process

The process for applying this Framework is summarized by Figure 1 and Figure 2.

Figure 1: Steps for Developing, Assessing, and Approving the Use of Remote Sensing Data to Quantify Forest Carbon

Arrows depict necessary checks and steps for refinement towards validation within the prescribed thresholds for accuracy and uncertainty.

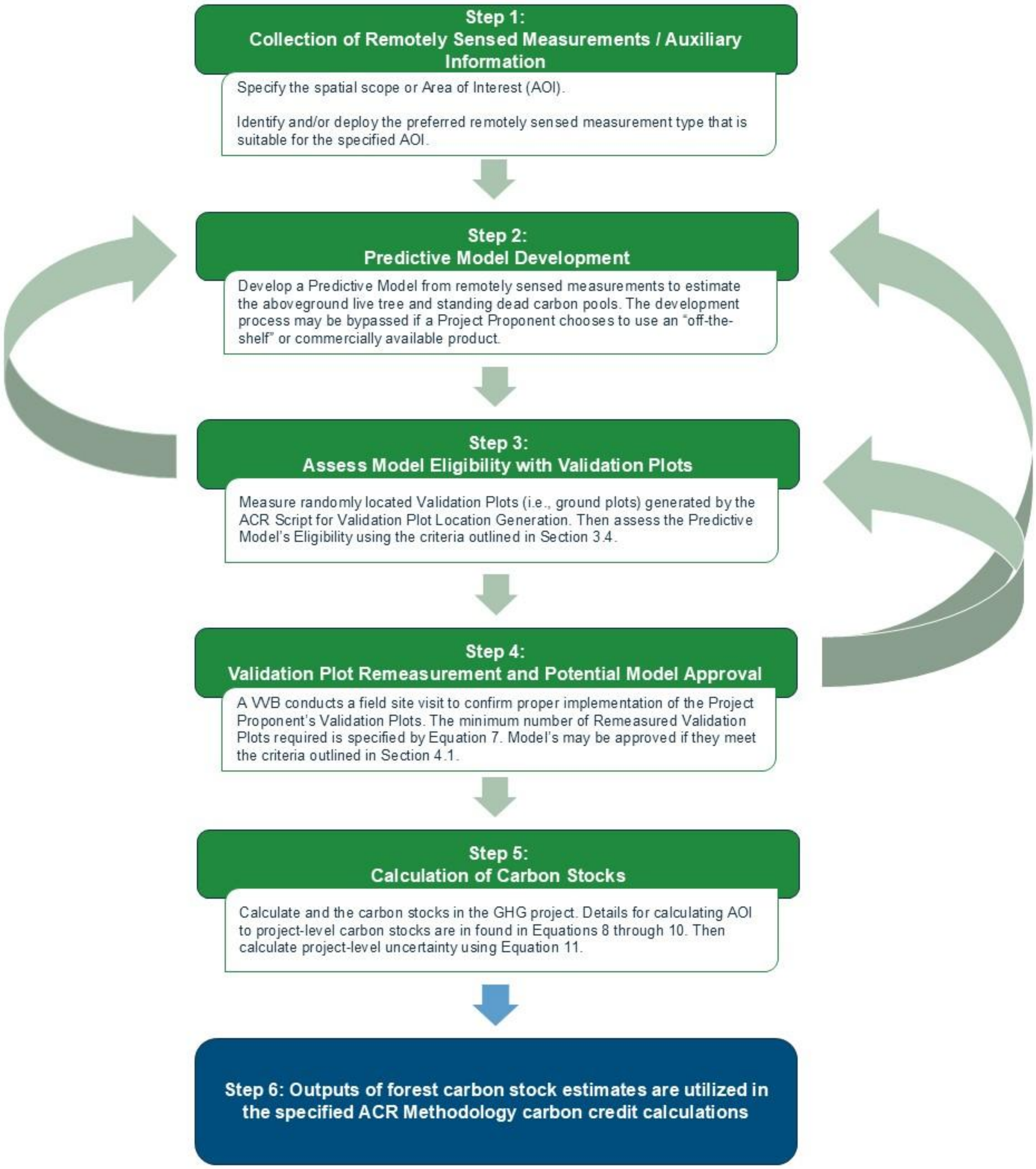
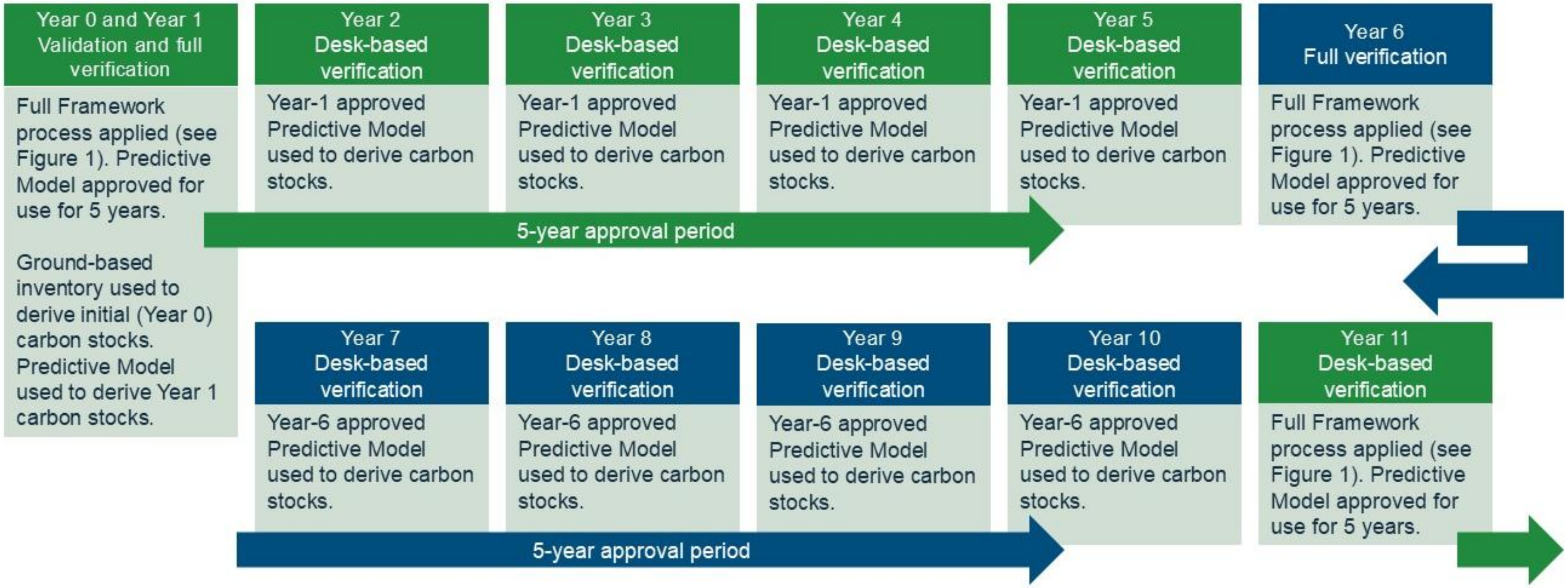


Figure 2: Example timeline of Framework approval process for a GHG Project.

Example application of the Framework for a GHG Project requiring a ground-based inventory to set the baseline (e.g., IFM). Project types that do not require a ground-based inventory to set the baseline may use approved remote sensing approaches to quantify initial (Year 0) carbon stocks.



2 Predictive Models

All projects utilizing this Framework must employ a Predictive Model meeting the specifications of this section. A Predictive Model may be developed by the Project Proponent, or a commercially available ("off the shelf") geospatial data product may be used. Predictive Models must estimate Pixel-level carbon densities prior to engaging in the Validation Plot process (Section 3).

2.1 Predictive Model Requirements

This Framework does not prescribe specific technologies or methods for developing Predictive Models or sourcing Remote Sensing data but rather sets thresholds for required accuracy relative to carbon estimates measured via ground-based sampling. The following minimum criteria are required for all Predictive Models:

- Each AOI must be spatially defined and completely covered by Pixels (see bullet below regarding interpolation, modeling, or other systematic approaches to assign carbon density to pixels with missing data).
- All Pixels within an AOI must be assigned a carbon density (in metric tons CO_2e/unit area) as an output from their respective Predictive Model.
- Carbon density must be treated as a continuous output per Pixel. Models that estimate carbon density in a category of Pixels (such as classification models) are ineligible.
- Predictive Models may utilize Remote Sensing measurements, Calibration Plot measurements, and/or other auxiliary data (e.g., soil or topographic data) for estimating carbon stocks. Eligible data sources may be publicly available or private and may include spatial (either raster or vector) or aspatial (e.g., Calibration Plot tree data) inputs. Multiple data sources may be used by a Predictive Model.
- The input data sources should represent the predicted time. If input data is infrequently collected, the data collected closest to the predicted time must be used unless data collected at another time can yield more accurate results for a specified and verifiable reason.
- Interpolation, modeling, or other systematic and verifiable approaches may be used to assign carbon density to Pixels with missing data (e.g., due to persistent cloud cover, sensor limitations). If these Pixels overlap with a randomly allocated Validation Plot area (Section 3.2), they must be sampled the same as any other Pixel and included in Validation Plot measurements.
- To preserve the accuracy of a Predictive Model's area-based outputs, an equal-area projection that minimizes local distortion should be used.

- A Predictive Model's carbon stock estimates derived from the implementation of this Framework are subject to the accuracy requirements established in the *ACR Standard* and the applied Methodology, inclusive of any deductions for uncertainty.

2.2 Predictive Model Design

Predictive Models may take the form of allometric models, gradient nearest neighbor models, random forest model, extreme gradient boosting models, or other algorithms meeting the definition of a Predictive Model (i.e., they produce a continuous output of carbon density per Pixel). Any type of Predictive Model may be approved for use if it successfully achieves statistical agreement with Validation Plots (Section 3) and if the Validation Plots statistically agree with the VVB's remeasurements (Section 4), as outlined in this Framework.

A GHG project area may be divided into multiple AOIs to intentionally limit a Predictive Model's spatial scope to improve the accuracy of carbon density estimation. To do so, areas with similar properties (e.g., topography, forest types, density classes, volume, age classes, management regime, or site index) could be grouped into one AOI, while areas with different properties would be grouped into another AOI. If the GHG project area includes more than one AOI, or if it includes areas that are not included in any AOI, a description of the AOI definition process must be provided (Section 6.1).

While a Predictive Model's algorithm is not subject to validation and/or verification, the VVB must ensure that an approved Predictive Model has not been modified from its originally approved state during its 5-year approval period (Section 1.5), which may require review of the algorithm at different points in time to ensure consistency.

2.3 Calibration Plots

At their discretion, Project Proponents may measure Calibration Plots and incorporate their measurements into the development of the Predictive Model. Calibration Plots do not need to adhere to this Framework's Validation Plot requirements (Section 3.2) or the *Validation Plot SOP document* (Section 6.1) and may be designed, allocated, and measured using any methods at the Project Proponent's discretion. The calculation of carbon stocks derived from Calibration Plot measurements are not required to adhere to the biomass estimation techniques prescribed by the applied Methodology. While not prohibited, Project Proponents applying previously existing ("off the shelf") geospatial data products are not required to measure and incorporate Calibration Plots.

It is expected that standardizing Calibration Plot measurements with Validation Plot measurements would likely increase the chances of statistical agreement (Section 3.4) and reduce uncertainty

(Section 5.4), but employing the same measurement approach across Calibration versus Validation plots is not required.

Project Proponents may measure and incorporate as many Calibration Plots as needed to adequately parameterize the Predictive Model. Measured Calibration Plots are not required to be incorporated into the Predictive Model (i.e., Calibration Plots may be omitted from final model development after measurement). If a GHG project has previously installed a Ground Plot-based inventory (e.g., for deriving initial carbon stocks for baseline development of an IFM project; Section 1.5.1), these plots may be repurposed as Calibration Plots.

With few exceptions (Section 3.2), Calibration Plot areas may not overlap with Validation Plot areas. As such, the location, size, and design of all Calibration Plots must be geospatially recorded to allow for a spatial intersection with Validation Plots. The monumentation of Calibration Plots must be sufficient to enable relocation during Validation Plot installation, enabling field foresters to ensure there is no overlap even if the geospatial intersection does not reveal a Validation Plot's overlap with a Calibration Plot. While the methods for measuring and incorporating Calibration Plots are not subject to review by the VVB, ensuring there is no overlap between Calibration Plots and Validation Plots is within the Validation and/or verification scope (Section 6.2).

Project Proponents may use a subset of Calibration Plots to test the predictive relationship between the Predictive Model and Calibration Plots using a cross-validation procedure to test model accuracy prior to installing Validation Plots.[1] If applying this procedure during Predictive Model development, the statistical results shall be calculated and reported (Section 6.1).

2.4 Mean Carbon Density

Once all Pixels for a particular Predictive Model have been assigned a carbon density, these values are averaged to calculate an AOI-level carbon density (Equation 1). If any Pixels within the AOI are located on a boundary which includes area outside the AOI, this average should be weighted by Pixel area inside the AOI.

[1] Picard, R. R., & Cook, R. D. (1984). Cross-validation of regression models. *Journal of the American Statistical Association*, 79(387), 575-583. https://doi.org/10.1080/01621459.1984.10478083

Equation 1: AOI-Level Mean Carbon Density

$$\bar{C}_{AG,i} = \sum_{p=1}^{N_i} C_{AG,p,i} \Big/ N_i$$

WHERE

$\bar{C}_{AG,i}$	Mean aboveground carbon density (in metric tons CO_2e/unit area) for AOI **i**.
$C_{AG,p,i}$	Aboveground carbon density (in metric tons CO_2e/unit area) for Pixel **p** within AOI **i**.
N_i	Total number of Pixels (**n**) within AOI **i**.

3 Assessing Model Eligibility with Validation Plots

Once a Project Proponent has used a Predictive Model to estimate Pixel-level and AOI-level carbon densities, they must assess the Predictive Model's eligibility by installing and measuring Validation Plots at randomly generated locations (Sections 3.1 and 3.2) and applying statistical tests (Section 3.3) to test for statistical agreement (Section 3.4). If statistical agreement is met, the Predictive Model is deemed eligible for approval and the Project Proponent may submit their Validation Plots for remeasurement by the VVB (Section 4).

To assess eligibility, each Predictive Model is assigned its own set of Validation Plots that occur exclusively within its AOI. A project that uses multiple Predictive Models will apply the following processes for each Predictive Model (Sections 3.1 through 3.4).

3.1 Validation Plot Location Generation

To initiate the assessment of Predictive Model eligibility with Validation Plots, the Project Proponent must first generate a sequence of randomly allocated points within each AOI using the R software environment and the *ACR Script for Validation Plot Location Generation*. This script requires a spatial file (in either .shp or .kmz format) for the defined AOI (Section 1.4) as an input. Each time the script is run to generate a sequence of points, the Project Proponent must request a seed number from ACR,[2] accompanied by the AOI spatial file and a desired number of points in the sequence (minimum of 45). For a given spatial file and seed number, the same set of randomly allocated points will be generated each time the script is run[3]. Once the seed number is entered into row number 33 of the script and the desired number of points is entered into row number 26, it is run to generate a sequence of randomly allocated points.

Each AOI must have a unique sequence of at least 45 points, and each AOI must have a minimum of 30 Validation Plots installed and measured (but can be more at the Project Proponent's discretion). 45 points is the default minimum number of points generated to ensure there is a sufficient number of Validation Plots if points must be skipped due to overlap with Calibration Plot areas or previously

[2] Seed number requests can be sent to ACRForestry@winrock.org.

[3] This approach ensures reproducibility and prevents the ability to run the script multiple times until a favorable sequence of points is generated.

installed Validation Plot areas (Section 3.2). Using the randomly allocated points as plot centers, the Project Proponent must install and measure Validation Plots following the predetermined sequence (Section 3.2).

3.2 Validation Plot Installation and Measurement

Validation Plots may be designed as either circular or square plots.[4] Validation Plots are not subject to any specific size requirements and they may encompass more than one single Pixel. Use or adaptation of inventory SOPs already applied in national forest monitoring systems such as the USDA FIA program,[5] available from published handbooks, or from the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (GPG) for Land Use, Land Use Change and Forestry (LULUCF)[6] is recommended. The Project Proponent must install and monument the Validation Plots such that they can be relocated by the VVB.

Validation Plots must only contain measurements from inside the AOI being examined. If any Validation Plots are located on a boundary which includes area outside of the AOI, the boundary must be mapped within the plot area and trees outside of the boundary must be excluded from the plot.

Validation Plots may not overlap with previously installed Validation Plots. Validation Plots may also not overlap with Calibration Plots, plus a buffer surrounding each Calibration Plot equal to the Validation Plot's diameter (if circular) or diagonal (if square). In the instance a randomly allocated point results in overlap, that point in the sequence must be skipped, and the Project Proponent must proceed with the next sequential point (e.g., when aiming to install 30 Validation Plots, plot (i.e., PointID) 31 is the first excess plot utilized).

Validation Plots must not be used as Calibration Plots (i.e., their data cannot be used to calibrate the Predictive Model) for the current Reporting Period. Validation Plots may only be repurposed to calibrate the Predictive Model only in the following two instances:

---

[4] Packalen, P., Strunk, J., Maltamo, M., & Myllymäki, M. (2023). Circular or square plots in ALS-based forest inventories—does it matter?. Forestry, 96(1), 49-61. https://doi.org/10.1093/forestry/cpac032

[5] U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program. (2023) Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.3. https://research.fs.usda.gov/sites/default/files/2024-02/wo-v9-3_sep2023_fg_nfi_natl.pdf

[6] Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. (2003) Good practice guidelines for land use, land-use change and forestry. ISBN 4-88788-003-0. https://www.ipcc.ch/site/assets/uploads/2018/03/GPG_LULUCF_FULLEN.pdf

- When developing a Predictive Model to be applied to a future Reporting Period, Validation Plots from past Reporting Periods may be used as Calibration Plots; or
- If the Predictive Model's eligibility assessment is restarted with a new sequence of Validation Plots (Section 3.4), the previous sequence's Validation Plots may be used as Calibration Plots.

Validation Plots must measure only the relevant pools included in the GHG project and estimated by the Predictive Model (i.e., if the GHG project does not include standing dead wood, the Validation Plot measurements should also not include standing dead wood). The measurements are then used to estimate carbon stocks.

Validation Plot-level carbon stocks must be estimated using one of the steps and biomass estimation techniques prescribed by the applied Methodology. If the GHG project has previously used a Ground Plot-based inventory to derive carbon stocks (e.g., at time 0), the same steps and biomass estimation techniques should be applied to derive Validation Plot-level carbon stocks. Since Predictive Models may not estimate belowground carbon stocks for either live biomass or standing dead wood, the belowground pool must be excluded from Validation Plot-level carbon stocks. Lastly, carbon stocks (in metric tons CO_2e) must be divided by the plot size to express carbon density in metric tons CO_2e per unit area.

Validation Plots must be installed and measured according to a *Validation Plot SOP document*, developed and provided by the Project Proponent for validation and verification. Please see Section 6.1 for further details.

3.3 Assessing Predictive Model Eligibility

When at least the minimum number of Validation Plots have been installed and measured, the Project Proponent must determine whether the Predictive Model's output statistically agrees with the carbon densities derived from Validation Plots using the following process:

To compare the Predictive Model's output with the Validation Plots, each Validation Plot must be paired with a Pixel or a group of Pixels. The Project Proponent must use geospatial software to map each Validation Plot area using the randomly allocated points as plot centers. Validation Plot areas are then geospatially intersected with the map of remotely sensed Pixels. The carbon densities from all Pixels overlapping the Validation Plot area must be averaged to derive the Predictive Model's area-weighted average carbon density for each Validation Plot area.

Equation 2: Area-weighted Average Carbon Density

$$\hat{C}_{AVE,AG,p,VP,i} = \frac{\sum Area_{p,VP,i} \times \hat{C}_{AG,p,VP,i}}{\sum Area_{p,VP,i}}$$

WHERE

$\hat{C}_{AVE,AG,p,VP,i}$	Predicted average aboveground carbon density (in metric tons CO_2e/unit area) for relevant carbon pools in all Pixel(s) **p** overlapping with the Validation Plot **VP** within AOI **i**, as derived from the Predictive Model.
$Area_{p,VP,i}$	Area (in hectares or acres) of Pixel **p** overlapping with Validation Plot **VP** within the AOI **i**.
$\hat{C}_{AG,p,VP,i}$	Predicted aboveground carbon density for relevant carbon pools (in metric tons CO_2e/unit area) for Pixel(s) **p** overlapping with the Validation Plot **VP** within AOI **i**, as derived from the Predictive Model.

The carbon density derived from each Validation Plot is treated as the observed value and compared to the Predictive Model's area-weighted average carbon density for each plot area. The differences between these two values (i.e., the errors) are used to calculate the Predictive Model's Root Mean Squared Error (RMSE; Equation 3). RMSE is then used to calculate uncertainty percentages for RMSE (Equation 4), the 90% confidence interval (Equation 5) and uncertainty percentage at the 90% confidence interval (Equation 6). These results are used to determine the Predictive Model's accuracy relative to the Validation Plots (Section 3.4).

Equation 3: Root Mean Squared Error

$$RMSE_i = \sqrt{\frac{\sum_{n=1}^{N_{VP,i}} \left(C_{AG,VP,i} - \hat{C}_{AVE,AG,p,VP,i}\right)^2}{N_{VP,i}}}$$

WHERE

$RMSE_i$	Root mean squared error (in metric tons CO_2e/unit area) for AOI **i**.
$C_{AG,VP,i}$	Observed aboveground carbon density (in metric tons CO_2e/unit area) for Validation Plot **VP** within AOI **I**, as derived from the Validation Plot.

$\hat{C}_{AVE,AG,p,VP,i}$	Predicted area-weighted average aboveground carbon density (in metric tons CO_2e/unit area) for Pixel(s) **p** overlapping with Validation Plot **VP** within AOI **i**, as derived from the Predictive Model.
$N_{VP,i}$	Total number of Validation Plots (**VP**) within AOI **i**.

Equation 4: Uncertainty Percentage using Root Mean Squared Error

$$UNC_{RMSE,i} = \left(\frac{RMSE_i}{\bar{C}_{AG,i}}\right) \times 100\%$$

WHERE

$UNC_{RMSE,i}$	Uncertainty percentage (%) using root mean squared error for AOI **i**.
$RMSE_i$	Root mean squared error (in metric tons CO_2e/unit area) for AOI **i**.
$\bar{C}_{AG,i}$	Mean aboveground carbon density (in metric tons CO_2e/unit area) for AOI **i**.

Equation 5: 90% Confidence Interval

$$CI_i = \left(\frac{RMSE_i}{\sqrt{N_{VP,i}}}\right) \times 1.645$$

WHERE

CI_i	Confidence interval (in metric tons CO_2e/unit area) at 90% confidence for AOI **i**.
$RMSE_i$	Root mean squared error (in metric tons CO_2e/unit area) for AOI **i**.
$N_{VP,i}$	Total number of Validation Plots (**VP**) within AOI **i**.

Equation 6: Uncertainty Percentage at 90% Confidence Interval

$$UNC_{CI,i} = \left(\frac{CI_i}{\bar{C}_{AG,i}}\right) \times 100\%$$

WHERE

UNC_{CIi}	Uncertainty percentage (%) using 90% confidence interval for AOI **i**.
CI_i	Confidence interval (in metric tons CO_2e/unit area) at 90% confidence for AOI **i**.
$\bar{C}_{AG,i}$	Mean aboveground carbon density (in metric tons CO_2e/unit area) for AOI **i**.

3.4 Statistical Agreement and Discontinuation

A Predictive Model is deemed to be in statistical agreement with Validation Plots, and hence eligible for deriving and reporting carbon stocks and uncertainty for its AOI, when the following conditions are met:

- The uncertainty percentage using RMSE ($UNC_{RMSE,i}$; Equation 4) is less than 20% (i.e., root mean squared error is less than 20% of the mean aboveground carbon density for relevant pools), and
- The uncertainty percentage using the 90% confidence interval ($UNC_{CI,i}$; Equation 6) is equal to or less than 10% (i.e., the confidence interval is equal to or less than 10% of the mean aboveground carbon density for relevant pools).

The Project Proponent may continue to install and measure Validation Plots following the predetermined sequence until both conditions for statistical agreement are reached, at which point the Predictive Model is deemed eligible. If the entire sequence has been exhausted and more points are needed for Validation Plot installation, the Project Proponent may request to generate new points to continue the sequence. The Project Proponent must inform ACR for approval prior to adding additional points to the sequence.

If statistical agreement cannot be reached, or at any other point at the Project Proponent's discretion, the Project Proponent may discontinue installation and measurement of Validation Plots.

- After discontinuation, the Project Proponent may further calibrate the Predictive Model using the discontinued sequence’s Validation Plot data as Calibration Plots, if desired.
- To re-initiate the Framework after discontinuation, the Project Proponent must request ACR approval to generate a new sequence of points to reinitiate the sequence from Section 3. All data collected at Validation Plots from the discontinued sequence is disgarded with respect to for testing statistical agreement.

4 Validation Plot Remeasurement

After the Project Proponent has successfully proven the model's eligibility (Section 3.4), the VVB must conduct a field site visit to confirm the implementation of their Validation Plot measurement SOPs. The VVB must conduct a remeasurement of a sample of the Validation Plots, to be carried out according to the following specifications:

- The VVB's Validation Plot remeasurements must statistically agree with the Project Proponent's Validation Plots measurements using a two-tailed Student's t-test at the 90% confidence interval. This test shall be paired.
- If the project contains multiple AOIs, remeasurements and a Student's t-test must be conducted for each Predictive Model.
- The minimum number of remeasured Validation Plots per Predictive Model and associated AOI shall be determined by calculating the square root of the number of Validation Plots installed by the Project Proponent using Equation 7.

Equation 7: Minimum Remeasured Validation Plot Count

$$\mathbf{n_{RemeasuredVP,i}} = \sqrt{\mathbf{N_{VP,i}}}$$

WHERE

$n_{RemeasuredVP,i}$	Minimum number of Validation Plots (VP) to be remeasured within AOI i.
$N_{VP,i}$	Total number of Validation Plots (VP) installed and measured by the Project Proponent within AOI i.

- The choice of which Validation Plots to remeasure is at the discretion of the VVB and may be based on a strategic assessment of risk, proportional carbon density, or other reasonable and demonstrably non-biased methods. Validation Plot selection and remeasurement order must be systematic and non-biased. This might be accomplished by assigning a remeasurement order to all Validation Plots prior to the field visit and progressing through the order until both the minimum number of remeasured Validation Plots and the required statistical agreement are reached.
- If a Validation Plot cannot be relocated in the field, the VVB may skip it and remeasure another Validation Plot. If many Validation Plots cannot be relocated, the VVB may perform an

assessment to determine whether the pattern is indicative of failed adherence to Validation Plot measurement SOPs, in which case the VVB may conclude that the Student's t-test has failed.

4.1 Model Approval

If the VVB's Validation Plot remeasurements reach statistical agreement with the Project Proponent's Validation Plot measurements, the Predictive Model is approved to calculate carbon stocks for its AOI for reporting in the GHG project.

If the VVB's Validation Plot remeasurements do not statistically agree with the Project Proponent's Validation Plot measurements, the Predictive Model is not considered eligible. If desired, the Project Proponent may request a new sequence of randomly allocated points to be measured by the Project Proponent as new Validation Plots, per Section 3 (Figure 1, Step 3).

Prior to installation of new Validation Plots and at their discretion, the Project Proponent may further calibrate the Predictive Model; previously measured Validation Plots may be treated as Calibration Plots for updating the Predictive Model, if desired (Figure 1, Step 2). Once new Validation Plots have been installed, the Project Proponent must apply the accuracy threshold specified above (Section 3.4) to assess the eligibility of the Predictive Model. If deemed eligible, new remeasurements are conducted by the VVB and newly installed Validation Plot data is tested for statistical agreement, per Section 4 (Figure 1, Step 3).

5 Calculation and Reporting of Carbon Stocks

This section describes the process for employing approved Predictive Models (Section 4.1) to calculate final carbon stocks for reporting in a GHG project.

5.1 Aboveground Carbon Stocks

For each approved Predictive Model, Project Proponent's must calculate carbon density by area to derive AOI-level carbon stocks.

Equation 8: AOI-Level Aboveground Carbon Stocks

$$\mathbf{C_{AG,i} = \bar{C}_{AG,i} \times Area_i}$$

WHERE

$C_{AG,i}$	Aboveground carbon stock (in metric tons CO_2e) for AOI $\mathbf{i}$.
$\bar{C}_{AG,i}$	Mean aboveground carbon density (in metric tons CO_2e/unit area) for AOI $\mathbf{i}$.
$Area_i$	Area (in hectares or acres)of AOI $\mathbf{i}$.

5.2 Belowground Carbon Stocks

Once AOI-level aboveground carbon stocks have been calculated, the result of Equation 8 shall be used as an input into a verifiable approach to calculate AOI-level belowground carbon stocks.

In selecting an approach to calculate belowground carbon stocks, Project Proponents should defer to the methods prescribed by the applied Methodology. GHG projects that derive initial carbon stocks for a ground-based inventory (i.e., not using this Framework) must apply the same approach to calculate belowground carbon stocks as was applied in the derivation of initial carbon stocks, if possible. If not possible (e.g., because the approach used to derive initial carbon stocks relies on a ground-based inventory and cannot be applied at the required AOI-level scale), then an alternative approach prescribed by the applied Methodology shall be employed. If the Methodology does not prescribe an appropriate approach, then Equation 1 from Mokany et al. (2006)[7] shall be applied.

Regardless of the approach taken, AOI-level belowground carbon stocks for relevant carbon pools must be added to aboveground carbon stocks prior to GHG project reporting.

Equation 9: AOI-Level Above- and Belowground Carbon Stocks

$$C_i = C_{AG,i} + C_{BG,i}$$

WHERE

C_i	Carbon stock (in metric tons CO_2e) for AOI i.
$C_{AG,i}$	Aboveground carbon stock (in metric tons CO_2e) for AOI i.
$C_{BG,i}$	Belowground carbon stock (in metric tons CO_2e) for AOI i.

5.3 Project-level Carbon Stocks

Project-level carbon stocks (Equation 10) for the relevant Reporting Period shall be calculated and reported for the GHG project across all relevant pools within the with-project scenario. Project-level carbon stocks must be used as inputs in project accounting per the applied Methodology to calculate Total GHG Emission Reductions and Removals.

If the AOI contains the entire GHG project area, the result of Equation 9 (i.e., AOI-level above- and belowground carbon stocks) equals the project-level carbon stocks, and Equation 10 may be skipped.

If the GHG project area includes more than one AOI, or if it includes areas not included in a Predictive Model's AOI (per Section 1.4), Equation 10 must be applied to combine the multiple carbon stock estimates into a single project-level carbon stock.

[7] Mokany, K., Raison, R. J., & Prokushkin, A. S. (2006). Critical analysis of root: shoot ratios in terrestrial biomes. *Global change biology*, *12*(1), 84-96. https://doi.org/10.1111/j.1365-2486.2005.001043.x

Equation 10: Project-level Carbon Stocks

$$C_{Total} = \left(\sum_{i=1}^{I} C_i\right) + C_x$$

WHERE

C_{Total}	Total carbon stock (in metric tons CO_2e) for the project area.
C_i	Carbon stock (in metric tons CO_2e) for AOI i.
I	Total number of Areas of Interest (i).
C_x	Carbon stock (in metric tons CO_2e) for areas not included in any AOI.

5.4 Project-Level Uncertainty

Project-level carbon stock values must be accompanied by an associated uncertainty percentage, expressed as a percentage of the carbon stock estimate.

Uncertainty in Project-level carbon stocks is the with-project scenario uncertainty for the relevant Reporting Period (e.g., $UNC_{P,t}$ in the *Improved Forest Management on Non-Federal U.S. Forestlands* Methodology), and it is used in project accounting per the applied Methodology to calculate any necessary deductions to Total GHG Emission Reductions and Removals.

If determined at the AOI level, uncertainty is calculated as a percentage using RMSE per Equation 4. If the AOI contains the entire GHG project area, then the result of Equation 4 is the project-level uncertainty, and Equation 11 may be skipped.

If the GHG project area includes more than one AOI, or if it includes areas that are not included in a Predictive Model's AOI (per Section 1.4), Equation 11 must be used to combine the multiple uncertainties into a single project-level uncertainty.[8]

[8] Equation 3.2 in: Frey, C., Penman, J., Hanle, L., Monni, S., Ogle, S. (2006) Uncertainties. In Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Ed.), *IPCC Guidelines for National Greenhouse Gas Inventories* (Volume 1, Chapter 3). IGES, Japan. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf

Equation 11: Project-level Uncertainty

$$\mathbf{UNC_{Total}} = \frac{\sqrt{\left(\mathbf{C_1} \times \mathbf{UNC_{RMSE,1}}\right)^2 + \left(\mathbf{C_2} \times \mathbf{UNC_{RMSE,2}}\right)^2 + \cdots + \left(\mathbf{C_I} \times \mathbf{UNC_{RMSE,I}}\right)^2 + \left(\mathbf{C_x} \times \mathbf{UNC_x}\right)^2}}{\left|\mathbf{C_1} + \mathbf{C_2} + \cdots + \mathbf{C_I} + \mathbf{C_x}\right|}$$

WHERE

UNC_{Total}	Total carbon stock (in metric tons CO_2e) for the entire project area.
C_i	Carbon stock (in metric tons CO_2e) for AOI $\mathbf{i}$, for example AOI $\mathbf{1}$.
$UNC_{RMSE,i}$	Uncertainty percentage (%) using root mean squared error for AOI $\mathbf{i}$, for example AOI $\mathbf{1}$.
I	Total number of Areas of Interest ($\mathbf{i}$).
C_x	Carbon stock (in metric tons CO_2e) for areas not included in any AOI.
UNC_x	Uncertainty percentage (%) for areas not included in any AOI, as calculated per the applied Methodology.

6 Reporting and Verification

6.1 Reporting

Each time this Framework is used, coincident with a GHG project's validation and/or a full verification to gain approval for one or more Predictive Models, the Project Proponent must develop a Remote Sensing standard operating procedures (SOP) document to be provided as a publicly available appendix to either the GHG Project Plan (if at validation) or the Monitoring Report (if in subsequent Reporting Period verifications). The Remote Sensing SOP is required in addition to any other inventory SOPs required by the applied Methodology.

The *Remote Sensing SOP document* must detail the technologies and methods employed to measure and predict carbon stocks in the GHG project. It must be verified by an ACR-approved VVB and must contain the following information:

- Summary of the GHG project's relevant carbon pools and associated uncertainty throughout its project term, presented as a table with the following columns:
    - Reporting Period's (i.e., dates) in the GHG project project term, starting with initial carbon stocks (i.e., time 0) and including every Reporting Period to date. Each Reporting Period is its own row.
    - Pools for carbon stocks and uncertainty for each reported time, including whether this Framework was employed or not, how many Predictive Models were used (with unique names/identifiers for each), whether there were areas not included in an Predictive Model AOI and (when relevant) a description of how carbon stocks and uncertainty for these areas were estimated.
- For each approved Predictive Model, provide the following:
    - First predicted time (i.e., the date) approved for use;
    - Start and end dates of the subsequent 5-year approval periods;
    - Reporting Periods (i.e., dates) within the 5-year approval period in which carbon stocks and associated uncertainty was calculated and reported using the approved model;
    - Map of the AOI within the GHG project area, delineated on a geographic information system (GIS). Areas not included in an AOI (but within the project area) must also be identified;
    - AOI area in acres or hectares;
    - Description of the Predictive Model's process for defining the Predictive Model's specific date of estimated carbon stocks (i.e., predicted time; Section 1.5.2). This description must

be sufficiently detailed to enable replication by both the Project Proponent and VVB during the 5-year approval period, including a clear identification of relevant input data sources and rules for determining the predicted time based on the input data;

- Relevant carbon pools (Section 1.6) and a detailed description of the steps taken to calculate belowground carbon stocks, where applicable (Section 5.2);
- Declaration of whether the Predictive Model was developed for the application of this Framework, or whether it has been applied and adapted from an existing geospatial product. If applying an existing geospatial product, provide the names of the authors of the Predictive Model, their affiliations, and any associated publications (if available);
- Description of the algorithm employed by the Predictive Model (e.g., allometric, gradient nearest neighbor, random forest, extreme gradient boosting, other generalized methods of computation);
- Descriptions of the input data sources used to develop and calibrate the Predictive Model, including the following:
  - For Remote Sensing measurements:
    - Description of Remote Sensing technologies (aerial, satellite or other technologies) employed to collect input data;
    - Description of measurements taken by Remote Sensing technologies, including the sensor type (e.g., LiDAR, optical imagery, radar, hyperspectral);
    - Spatial resolution of the Remote Sensing measurements (e.g., 10 meter);
    - Details regarding the timing of data collection (i.e., temporal resolution) and any steps taken to compile data collected over a period of time.
  - For alternative auxiliary data:
    - Description of the data source and what is represents;
    - Explanation of why the auxilary data is expected to predict carbon density;
    - Whether the auxiliary data is vector or raster data, and if raster, the spatial resolution of the auxiliary data;
    - Details regarding the timing of data collection (i.e., temporal resolution) and any intermediate steps taken to compile data if collected over a period of time.
  - For Calibration Plots:
    - Number of Calibration Plots incorporated into the Predictive Model;
    - Whether Calibration Plots were newly installed, or previously installed and repurposed. If repurposed, describe the source and original purpose of the previously installed plots;
    - Plot size and design, plot location procedures, and plot monumentation;
    - Summary of the field measurement protocol(s) applied;

        - Details regarding the timing of data collection and any steps taken to compile data (e.g., modeling to a different point in time); and
        - If a subset of Calibration Plots were used in a cross-validation procedure prior to installing Validation Plots, provide a summary of the procedure, including the number and percentage of Calibration Plots withheld for accuracy testing and the resulting Root Mean Squared Error and 90% Confidence Interval.
    - For each input data source, provide:
        - Whether it is publicly available or private;
        - Summary of how it is used by the Predictive Model.
- Description of the approach used to assign carbon density to Pixels with missing data, if applicable, including the following:
    - Map depicting coverage and completeness (i.e., identifying Pixels with missing data) within the AOI;
    - Number and percentage of Pixels with missing data within the AOI and associated area equivalent in acres/hectares as appropriate;
    - General explanation regarding why the data is missing (e.g. cloud coverage, unfit terrain);
    - Approach(es) used to assign carbon denity to Pixels with missing data; and
    - Any systematic rules applied in assigning carbon density to pixels with missing data.
- Mean carbon density for the AOI (Equation 1);
- A detailed description of the process for assessing Predictive Model eligibility with Validation Plots (Section 3), including:
    - Summary of the process, including how many point sequences were generated, whether any sequences of Validation Plots were discontinued and, if so, why;
    - Map depicting Validation Plot locations within the AOI, provided in a GIS file format
    - *Validation Plot SOP document*, provided as a subsection of the *Remote Sensing SOP document*, describing the Validation Plot inventory process in detail, including:
        - Number of Validation Plots installed;
        - The sequence of points generated by the ACR Script for Validation Plot Location Generation and the associated Validation Plot IDs;
        - Whether any Validation Plots in the sequence were skipped due to overlap with Calibration Plot areas;
        - Plot size and design, in-field plot location procedures, and monumentation;
        - Process for mapping in-plot boundaries and excluding trees from measurement when a Validation Plot is located on a boundary which includes area outside of the AOI;

        - Plot data collected and measurement tools used;
        - Plot measurement procedures such that measurements are systematic and repeatable;
        - Decay classification of standing dead wood, if an included pool;
        - Process for recording missing volume, or tree class code as applicable, and how corresponding deductions for unsound wood were applied;
        - Biomass estimation technique per the applied Methodology;
        - Components of the tree selected for biomass quantification; and
        - Data management systems and processes, including quality assurance / quality control (QA/QC) procedures.
      - Summary table of the intersection of Pixels with the Validation Plots, and a list of the resulting area-weighted average carbon densities for each Validation Plot (Equation 2);
      - Root mean squared error (Equation 3), the associated uncertainty percentage (Equation 4), and whether the result of Equation 4 is less than 20%;
      - 90% Confidence Interval (Equation 5), the associated uncertainty percentage (Equation 6), and whether the result of Equation 6 is equal to or less than 10%;
  - Aboveground carbon stocks (Equation 8) and above- and belowground carbon stocks (Equation 9) in metric tons CO_2e.
- If multiple AOIs are defined within the project area, or if there are areas not included in an AOI, provide the following:
  - Summary of the datasets, tools, and process for defining each AOI;
  - Explanation of why a single Predictive Model was not developed for the entire project area, and if applicable, why certain areas were excluded from the AOIs and Predictive Model development;
  - Carbon stocks for areas not included in an AOI (C_x), the associated uncertainty percentage (UNC_x), and a description of how these values were derived; and
  - Project-level carbon stocks (Equation 10) and project-level uncertainty (Equation 11).
- Description of the QA/QC methods applied in implementation of this Framework (from data collection through carbon stock reporting), including data management systems, processes, and procedures.
- Participating entities involved in the implementation of this Framework and their roles and responsibilities.

When employing this Framework to report carbon stocks and uncertainty using a previously approved Predictive Model during its 5-year approval period, the following updates must be provided:

- An updated summary table of the GHG project's sources for carbon stocks and uncertainty throughout its project term (2nd bullet of the *Remote Sensing SOP document*, above) including the current Reporting Period and its sources for carbon stocks and uncertainty;
- Detailed list of all newly collected Remote Sensing measurements or other input data sources processed by the approved model for the predicted time;
- Details regarding the timing of data collection (i.e., temporal resolution) for the newly collected Remote Sensing measurements and/or other input data sources and any steps taken to compile data collected over a period of time;
- Description of how the previously reported process for defining the predicted time was replicated using the newly collected input data sources;
- A detailed summary of all calculations for this Reporting Period, including:
  - AOI-level mean carbon densities (Equation 1);
  - AOI-level aboveground carbon stocks (Equation 8), above- and belowground carbon stocks (Equation 9);
  - AOI-level uncertainties (fixed throughout the 5-year approval period; Equation 3);
  - If applicable, carbon stocks for areas not included in an AOI (C_x), the associated uncertainty percentage (UNC_x), and a description of how these values were derived; and
  - Project-level carbon stocks (Equation 10) and project-level uncertainty percentage (Equation 11) to be used in GHG project accounting this Reporting Period.
- Any other updates to the previously reported information in the *Remote Sensing SOP document*.

6.2 Validation and Verification

The applicability, implementation, and results of this Framework are subject to validation (if applied to derive initial carbon stocks) and/or verification by a VVB, including a ground-based remeasurement of the Validation Plots (Section 4) to confirm the implementation of the Validation Plot SOPs. VVBs must ensure that the Remote Sensing SOP and all reporting is complete and accurate (Section 6.1) and that all calculations are implemented in accordance with this Framework (Sections 2 through 5) and the applied Methodology.

In addition to the scope set out by the *ACR Standard*, the *ACR Validation and Verification Standard*, and the applied Methodology, validation and/or verification must assess:

- AOI definitions;

- The predicted time definition process (section 1.5.2) and how it is applied;
- How the Predictive Model(s) adheres to the requirements of Section 2.1;
- Whether an approved Predictive Model's has been modified from its originally approved state during its 5-year approval period (desk verifications only);
- The correct geospatial location of installed Validation Plots relative to the generated sequence of points (full verifications only);
- Whether there is any overlap between Validation Plots area with one another or with Calibration Plot areas (full verifications only);
- Implementation of procedures for installing, measuring, and estimating carbon stocks from Validation Plots (full verifications only; Section 4);
- The methods applied for calculating belowground carbon stocks;
- The calculation of all applicable Equations in this Framework, for deriving to the project-level carbon stocks and uncertainty; and
- The QA/QC methods applied.

The Project Proponent must provide documentation and data to facilitate the required validation and/or verification activities. This process must be fully documented in the Validation Report (if this Framework is applied at validation) or Verification Report (if in subsequent Reporting Periods), including any relevant literature, references, interviews, and other information reviewed in corroborating the implementation of the Framework. The description of the Validation Plot remeasurement effort must detail how it conforms to the specifications in Section 4. All issues regarding this Framework must be documented and resolved in an issues log pertaining to the validation and/or verification of the GHG Project.

Definitions

Area of Interest (AOI)	A Predictive Model's spatial scope. An AOI must be associated with a single Predictive Model. An AOI may contain either the entire GHG project area or only a part of it.
Calibration Plot	A type of Ground Plot measured by the Project Proponent to calibrate the Predictive Model.
Ground Plot	Sample of the project area using measurements collected in the field.
Pixel	A discrete geographic area used as a unit for carbon density estimation by the Predictive Model. Pixels must be uniformly sized and may not geographically overlap.
Predictive Model	Algorithm that utilizes Remote Sensing data or alternative auxiliary information to estimate carbon density for each Pixel. Predictive Models must produce a continuous output per Pixel; models whose output is a classification of Pixels are ineligible.
Remote Sensing	Acquiring data from a distance, typically from satellite or aircraft, including (but not limited to) aerial imagery, Light Detection And Ranging (LiDAR), Radio Detection And Ranging (RADAR), or multispectral imagery.
Validation Plot	A type of Ground Plot measured by the Project Proponent to assess the eligibility of the Predictive Model. Validation Plot locations are randomly generated using the ACR Script for Validation Plot Location Generation. A subset of Validation Plots is remeasured by the VVB according to Section 4.

Appendix A: References

Frey, C., Penman, J., Hanle, L., Monni, S., Ogle, S. (2006) Uncertainties. In Eggleston, S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Ed.), *IPCC Guidelines for National Greenhouse Gas Inventories* (Volume 1, Chapter 3). IGES, Japan. https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_3_Ch3_Uncertainties.pdf

Mokany, K., Raison, R. J., & Prokushkin, A. S. (2006). Critical analysis of root: shoot ratios in terrestrial biomes. *Global change biology*, *12*(1), 84-96. https://doi.org/10.1111/j.1365-2486.2005.001043.x

Packalen, P., Strunk, J., Maltamo, M., & Myllymäki, M. (2023). Circular or square plots in ALS-based forest inventories—does it matter?. *Forestry*, 96(1), 49-61. https://doi.org/10.1093/forestry/cpac032

Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. (2003) Good practice guidelines for land use, land-use change and forestry. ISBN 4-88788-003-0. https://www.ipcc.ch/site/assets/uploads/2018/03/GPG_LULUCF_FULLEN.pdf

Picard, R. R., & Cook, R. D. (1984). Cross-validation of regression models. *Journal of the American Statistical Association*, 79(387), 575-583. https://doi.org/10.1080/01621459.1984.10478083

Berbeyen, T., Nguyen, T., Swan, A. (2025). Statistics LibreTexts. *6.3: The Central Limit Theorem.* https://stats.libretexts.org/Courses/Citrus_College/Introductory_Statistics_OER_-_Exercise_Questions_Each_Section_Included/06%3A_Continuous_Probability_Distribution/6.03%3A_The_Central_Limit_Theorem

U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program. (2023) Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.3. https://research.fs.usda.gov/sites/default/files/2024-02/wo-v9-3_sep2023_fg_nfi_natl.pdf