American Carbon Registry
AT WINROCK INTERNATIONAL

METHODOLOGY FOR THE QUANTIFICATION, MONITORING, REPORTING AND VERIFICATION OF GREENHOUSE GAS EMISSION REDUCTIONS AND REMOVALS FROM

AVOIDED CONVERSION OF U.S. FORESTS TO ALTERNATIVE LAND USES

VERSION 1.0

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American Carbon Registry®

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ABOUT AMERICAN CARBON REGISTRY® (ACR)

A leading carbon offset program founded in 1996 as the first private voluntary GHG registry in the world, ACR operates in the voluntary and regulated carbon markets. ACR has unparalleled experience in the development of environmentally rigorous, science-based offset methodologies as well as operational experience in the oversight of offset project verification, registration, offset issuance and retirement reporting through its online registry system.

ACKNOWLEDGEMENTS

This methodology is dedicated to the memory of D. Hunter Parks (1976 – 2022). Hunter's lifelong passion for conservation, his inspiration and insight, and years of experience in helping pioneer the forest carbon market enabled the creation of this methodology. May his legacy of conservation live on through the unique natural places that are conserved each time an avoided conversion project is developed.

The authors would also like to acknowledge our families, friends, and colleagues whose love and support made this methodology possible. Additionally, Green Assets and the American Carbon Registry would like to recognize the Natural Resources Conservation Service of the USDA and the Division of Forestry & Natural Resources at West Virginia University for the expert technical support provided to produce this methodology.

This methodology was developed by Green Assets, Inc. in conjunction with the American Carbon Registry

ACRONYMS AND DEFINITIONS

ACR	American Carbon Registry
ATFS	American Tree Farm System
Activity-Shifting Leakage	Conversion of forestland outside of the project area to alternative land uses in response to the avoided conversion of the project area.
BIA	Bureau of Indian Affairs
Cm	Centimeters
CO_2	Carbon Dioxide. All pools and emissions in this methodology are represented by either CO_2 or CO_2 equivalents. Biomass is converted to carbon by multiplying by 0.5 and then to CO_2 by multiplying by the molecular weight ratio of CO_2 to Carbon (3.664).
CO_2e	Carbon dioxide-equivalents. The number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas.
Commercial Harvesting	Any type of harvest producing merchantable material at least equal to the value of the direct costs of harvesting. Harvesting of dead, dying, or threatened trees (regardless of merchantability) is specifically excluded from this definition where a signed attestation from a professional forester is provided, confirming the harvests are in direct response to isolated forest health (insect/disease) or natural disaster event(s) not part of a long-term harvest regime.
Crediting Period	The period of time in which the baseline is considered to be valid and project activities are eligible to generate ERTs. 40 years.
DBH	Diameter at breast height
De minimis	So minor as to merit disregard. Threshold of 3% of the final calculation of emission reductions and removals.

Emission Reduction	The measured decrease of GHG emissions over a specific period relative to an approved baseline. In the context of this methodology, emission reductions are carbon stock changes attributable to the baseline scenario.
ERT	Emission Reduction Ton
Ex ante	Prior to the occurrence and verification of a project emission mitigation activity.
Ex post	After the event, a measure of past performance.
FIA	Forest Inventory and Analysis Program of the USDA Forest Service
FMV	Fair market value
FSC	Forest Stewardship Council
Forestland	Land with at least 10 percent cover (or equivalent stocking) by live trees of any size, or land formerly having such tree cover, and not currently developed for non-forest uses. Forestland must be at least 1 acre in size. Land proposed for inclusion in the project area shall meet the cover requirement, in aggregate, over the entire area.
GHG	Greenhouse gas
GIS	Geographic Information System
GWP	Global Warming Potential
gSSURGO	Gridded Soil Survey Geographic
HBU	Highest and best use. The land use which results in the maximum return or profit for the landowner as identified in a qualified appraisal.
IPCC	Intergovernmental Panel on Climate Change
Market Leakage	Increases in harvest levels on lands outside the project area due to shifts in the supply of and demand for wood products.
Mineral Soil	A soil consisting predominantly of, and having its properties determined predominantly by, mineral matter. For this methodology, this includes all soils which do not meet the definition of organic soils.

Minimum Project Term	The minimum period for which a Project Proponent commits to project monitoring and verification. 40 years.
Native Species	Trees listed as native to a particular region by the Native Plant Society, SAF Forestry Handbook, or State-adopted list.
Organic Soil	A soil in which the sum of the thickness of layers containing organic soil materials is generally greater than the sum of the thickness of mineral layers. For this methodology, in line with USDA soil taxonomy, this includes all Histosols except Folists and all Histels (suborder of Gelisols) except Folistels.
PDA	Programmatic Development Approach
Professional Appraiser	An individual licensed to engage in the profession of real estate appraisals. The individual must be certified in at least one of the state jurisdictions in which the project is located and be a member of the Appraisal Institute (MAI designation).
Professional Forester	An individual engaged in the profession of forestry. If a project is in a jurisdiction that has professional forester licensing laws, the individual must be credentialed in that jurisdiction.[1] Otherwise, the individual must be certified by the Society of American Foresters or Association of Consulting Foresters.
Project Proponent	An individual or entity that undertakes, develops, and/or owns a project. This may include the project investor, developer, and/or owner of the lands/facilities on which project activities are conducted. The Project Proponent and the land, surface, and/or mineral rights owner may be different entities.
QA/QC	Quality assurance / quality control
Removal	The mass of GHGs removed from the atmosphere over a specific period relative to an approved baseline. In the context of this methodology, removals are carbon stock changes resulting in sequestration attributable to the with-project scenario.
Reporting Period	The period of time covering a GHG assertion for a single verification and subsequent request for ERT issuance.

[1] For projects located in multiple jurisdictions with professional forester licensing laws, the individual must be credentialed in at least one of the jurisdictions.

Reversal	An intentional or unintentional event that results in emission into the atmosphere of stored or sequestered CO_2e for which offset credits were issued, as further defined by the *ACR Standard.*
SFI	Sustainable Forestry Initiative
SOC	Soil organic carbon
SOP	Standard operating procedures
Start Date	The point in time when project crediting begins, coinciding with the start of the first crediting period and as further defined by section 2.3 of this methodology and the *ACR Standard.*
Ton	A unit of mass equal to 1000 kg.
Tree	A perennial woody plant with a diameter at breast height (4.5’) greater than or equal to 1” with the capacity to attain a minimum diameter at breast height of 5” and a minimum height of 15’ (shrub species are not eligible).

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EQUATIONS

1 METHODOLOGY DESCRIPTION

1.1 METHODOLOGY SUMMARY

This methodology provides procedures for determining eligibility, assessing additionality, and quantifying, monitoring, reporting, and verification of GHG emission reductions and removals of carbon projects that avoid the conversion of non-federal U.S. forestland to alternative land uses.

ERTs are based on GHG emission reductions associated with baseline land use conversion activities and GHG removals from retention of with-project forest growth. Projects must commit to conservation of forestland through a legally binding mechanism.

The baseline scenario is a project-specific projection of carbon stock changes resulting from conversion of the project area to non-forest. The baseline is developed by 1) determining the highest and best use (HBU) for the project area via an appraisal, 2) identifying the rate of conversion, and 3) modeling changes in carbon stocks over the crediting period based on the identified conversion schedule.

Projects that avoid conversion to agricultural land use may elect to account for the avoided emissions associated with soil disruption and fertilizer application. Both activity shifting and market effects leakage are accounted for in project quantification.

1.2 APPLICABILITY CONDITIONS

- This methodology is applicable only to non-federally owned forestland within the United States. Tribal lands in the United States not under BIA control or management that meet the applicability conditions of this methodology and the requirements of the relevant *ACR Standard* are eligible.[2]
- Project area lands must be legally convertible by entities owning or controlling carbon and surface rights to one of the following alternative land uses:
    - Agriculture;
    - Mining; or
    - Commercial, residential, or recreational development.
- Participating entities (e.g., Project Proponent, landowner) must demonstrate ownership and control of carbon, timber, and surface rights and land title for the entirety of the project area

[2] See also ACR Guidance for Carbon Project Development on Tribal Lands available under the Guidance, Tools & Templates section of the ACR website.

at the project start date and throughout the crediting period. Projects that avoid conversion to mining must also demonstrate ownership and control of mineral rights.

- A qualified appraisal (required per section 2.4.2) must demonstrate that the project's GHG emission reductions and removals are additional under this methodology.
- Forestland where adequately stocked stands of native species were converted to non-native species within 10 years of project start date is ineligible. The planting of, or management for, non-native species is prohibited.
- Each tract/parcel or stand comprising the project area(s) must minimally be 10 acres in size, and each landowner must enroll at minimum 40 acres.
- All project areas must either enact a conservation easement or transfer surface rights (mineral rights must also be transferred for projects that avoid conversion to mining) to a land trust or other conservation organization per Section 2.1.1.

1.3 SUSTAINABLE MANAGEMENT REQUIREMENTS

All projects must adhere to the following sustainable forest management requirements throughout the crediting period:

- Project areas subject to commercial harvesting at the project start date in the with-project scenario must adhere to at least one of the following:
  - Be certified by FSC, SFI, or ATFS or become certified within one year of the project start date;
  - Be enrolled in a state sanctioned forestry program with monitoring and enforcement mechanisms in place;
  - Private landowners owning more than 2,500 acres may provide a documented long-term forest management plan, demonstrating sustainable forest management (per section 1.3.1), prepared and signed by a professional forester; or
  - Tribal lands may utilize one or more of the sustainable management demonstrations above or, in the absence of such verifiable evidence, must adhere to sustainable forest management practices informed by traditional knowledge. Where possible, practices informed by traditional knowledge should be evidenced by a document such as a traditional land use plan, but it is recognized that principles of traditional land use are often not documented and exist only in oral communication.
- If the project is not subject to commerical harvest within the project area as of the project start date, but harvests occur later in the project life cycle, the project area must meet the requirements outlined above before commercial harvesting may occur.

1.3.1 Small Landowner Forest Management Plan Requirements

Private landowners owning less than 2,500 forested acres may fulfill the sustainable management requirement by providing a documented long-term forest management plan prepared and signed by a professional forester. Projects must identify how their plan is compatible with Criteria 1 through 6 of the Montréal Process Criteria and Indicators.[3] Criterion 5 (Maintenance of forest contribution to global carbon cycles) is satisfied by enrollment in the carbon project. Criterion 7 (Legal, institutional and economic framework for forest conservation and sustainable management) is not relevant at the project scale and therefore not considered.

Compatibility with the Montréal Process Criteria may be reported within the forest management plan or as an addendum using the form found on the reference documents section of this methodology's website. References to specific Indicators from the Montréal Process may be provided but are not required.

1.4 POOLS AND SOURCES

CARBON POOLS	INCLUDED / OPTIONAL / EXCLUDED	JUSTIFICATION / EXPLANATION OF CHOICE
Aboveground live biomass carbon	Included	Major carbon pool subjected to the project activity.
Belowground live biomass carbon	Included	Major carbon pool subjected to the project activity
Aboveground standing dead wood	Optional	Project Proponents may elect to include the pool. Where included, belowground standing dead wood must also be included, and the pool must be estimated in both the baseline and with-project scenarios.
Belowground standing dead wood	Optional	Project Proponents may elect to include the pool. Where included, aboveground standing dead wood

[3] https://montreal-process.org/The_Montreal_Process/Criteria_and_Indicators/index.shtml

CARBON POOLS	INCLUDED / OPTIONAL / EXCLUDED	JUSTIFICATION / EXPLANATION OF CHOICE
		must also be included, and the pool must be estimated in both the baseline and with-project scenarios.
Lying dead wood	Optional	Project Proponents may elect to include the pool. Where included, the pool must be estimated in both the baseline and with-project scenarios.
Harvested wood products	Included	Major carbon pool subjected to the project activity.
Litter / Forest Floor	Excluded	Changes in the litter pool are considered *de minimis* as a result of project implementation.
Soil organic carbon	Optional/Excluded	Where the identified baseline land use is agriculture, Project Proponents may elect to include this pool in the baseline scenario. Where included, this pool is conservatively assumed to remain static in the with-project scenario. Soil organic carbon is conservatively excluded where the identified baseline land use is mining or development.

GAS	SOURCE	INCLUDED / EXCLUDED	JUSTIFICATION / EXPLANATION OF CHOICE
CO_2	Burning of biomass	Excluded	Carbon emissions due to burning are accounted as a carbon stock change.
CH_4	Burning of biomass	Excluded	Potential emissions are negligible.
N_2O	Burning of biomass	Excluded	Potential emissions are negligible.

GAS	SOURCE	INCLUDED / EXCLUDED	JUSTIFICATION / EXPLANATION OF CHOICE
N_2O	Fertilizer application	Optional/Excluded	Where the identified baseline land use is agriculture, Project Proponents may elect to include this pool. Where included, the pool must be accounted in both the baseline and with-project scenarios. Where the identified baseline land use is mining or development, potential emissions are negligible, and this pool is excluded.
CH_4/N_2O	Livestock Production	Excluded	Emissions are assumed to be greater in the baseline scenario than in the with-project scenario.
N_2O	Machinery Use	Excluded	Emissions from machinery are assumed to be greater in the baseline scenario than in the with-project scenario.

LEAKAGE SOURCE		INCLUDED / OPTIONAL / EXCLUDED	JUSTIFICATION / EXPLANATION OF CHOICE
Activity-Shifting	Displacement of alternative land use to other forestlands	Included	If conversion of forestland to alternate uses is avoided in the project area, shifts in supply and demand may focus forestland conversion to lands outside the project area.
Market Effects	Timber harvesting	Included	Reductions in product outputs due to project activity may be compensated for by other forestlands in the marketplace. Those emissions must be included in the quantification of project benefits.

2 ELIGIBILITY, BOUNDARIES, ADDITIONALITY, AND PERMANENCE

2.1 PROJECT ELIGIBILITY

This methodology applies to non-federally owned U.S. forestlands that are able to document 1) clear land title, surface rights, and, for projects that avoid conversion to mining only, mineral rights and 2) offsets title. Projects must also meet all other requirements of Table 4 of the *ACR Standard* version effective at project listing or crediting period renewal.

This methodology applies to lands that 1) could be legally converted to non-forest uses by entities owning or controlling surface, timber, and mineral rights (only applicable to projects that avoids conversion to mining) and 2) are additional per the benchmark performance standard and regulatory surplus test.

Proponents must demonstrate that the project area, in aggregate, meets the methodology definition of forestland.

2.1.1 Conservation Commitment

To be eligible under this methodology, Project Proponents must demonstrate a legally documented commitment to conservation that is minimally in effect through the end of the minimum project term, through one of the following options:

- Establishing a conservation easement that refers to the requirements of this methodology, applies to current and all subsequent forest owners, and prevents the conversion of the project area to the HBU specified by the qualified appraisal (section 2.4.2). To qualify under this methodology, the conservation easement must:
    - Be legally granted by the individual or entity with the project area's land title and surface and mineral rights (for projects avoiding conversion to mining only) to an eligible easement holder. An eligible easement holder is a non-profit organization legally established under 501(c)(3) of the Internal Revenue Code whose mission includes land conservation; and
    - Minimally geographically encompass the boundary of the project area.

- Transfering the surface and mineral rights (for projects avoiding conversion to mining only) ownership to a land trust or other conservation organization who directly commits to a restriction on conversion of the project area to the HBU specified by the qualified appraisal (section 2.4.2) via either an accepted deed restriction or a legally binding contract. Offsets title must be retained by the Project Proponent. In order to qualify under this methodology, the deed restriction or contract must:
  - Be legally executed between the individual or entity with clear land title and surface and mineral rigths (for projects avoiding conversion to mining only) and a non-profit organization legally established under 501(c)(3) of the Internal Revenue Code whose mission includes land conservation; and
  - Minimally geographically encompass the boundary of the project area.

The conservation commitment is subject to validation. Conservation easements must be enacted no more than one year before or three years after project start date. Transfers of ownerships must be finalized no more than one year before or three years after project start date.

2.2 PROJECT GEOGRAPHIC BOUNDARY

The Project Proponent must provide a detailed description of the geographic boundary of project activities. Note that the project activity may contain more than one discrete area of land, that each area must have a unique geographical identification, and that each area must meet the eligibility requirements. Information to delineate the project boundary must include the following:

- Project area map, delineated on a geographic information system (GIS);
- General location map; and
- Property parcel map.

Aggregation of forest properties with multiple landowners, including PDA, is permitted under this methodology consistent with Chapter 6 of the *ACR Standard* as a means to reduce per-acre transaction costs of inventory and verification.

2.3 PROJECT TEMPORAL BOUNDARY

The project start date may be denoted by one of the following:

- The date of signing or enactment of a conservation easement with terms outlined in section 2.1.1;
- The date of signing of a corporate or board resolution, or entering a contractual agreement, to establish a conservation easement with terms outlined in section 2.1.1;

- The date of entering a contractual agreement for, or date of, transfer of ownership of surface and mineral rights (for projects avoiding conversion to mining only) to a land trust or other conservation organization as per the terms outlined in section 2.1.1; or
- The date that the Project Proponent first demonstrated good faith effort to implement a carbon project. Such demonstrations must include documented evidence of:
  - The date the Project Proponent initiated a forest inventory for the carbon project;
  - The date that the Project Proponent entered into a contractual relationship or signed a corporate or board resolution to implement the carbon project; or
  - The date the project was submitted to ACR for listing review.

Other dates may be approved as the start date on a case-by-case basis.

In accordance with the *ACR Standard*, projects will have a crediting period of forty (40) years. The minimum project term is forty (40) years. The minimum project term begins on the project start date (not the first or last year of crediting). Projects may renew for subsequent crediting periods per section 4.3. Projects must be validated within 3 years of the project start date.

2.4 ADDITIONALITY

2.4.1 Regulatory Surplus Test

As required by the *ACR Standard*, projects must establish regulatory additionality, demonstrating that existing laws, regulations, statutes, legal rulings, deed restrictions, or other regulatory frameworks relevant to the project area do not restrict the conversion of the project area to alternative non-forest land uses. Unless established in support of project activities (section 2.1.1), all legally binding conditions of easements in place for more than one year prior to start date must also be considered. Voluntary agreements without an enforcement mechanism, proposed laws or regulations, optional guidelines, or general government policies are not considered in the regulatory surplus test. Regulatory surplus must be assessed at each verification. Newly enacted legal requirements that prohibit land conversion in the project area may make the project non-additional from the time of enforceability going forward, but previously issued ERTs and prior eligibility are not affected. Baseline conversion activities are assumed to be completed according to their temporal land conversion rate (section 4.1), and once conversion is complete, demonstration of regulatory surplus is unnecessary.

2.4.2 Benchmark Performance Standard

A qualified appraisal is required to demonstrate the threat of conversion and that a project surpasses the performance standard. For an appraisal to be qualified, it must be completed in accordance with the Uniform Standards of Professional Appraisal Practice,[4] be prepared and signed by a professional appraiser, be geographically representative of the project area, and contain the following components:

- Determination of the project area's FMV under its current forested, or As Is, use;
- Identification of the project area's HBU and determination of FMV under its HBU; and
- Description of how the project area is physically suitable for conversion to its identified HBU, including:
  - Topographical considerations;
  - Suitability of soils for agricultural use purposes, if applicable;
  - Availability of water for agricultural use purposes, if applicable;
  - Availability and extractability of mineral resources, if applicable;
  - Suitability of existing infrastructure (transportation and utilities) for commercial, residential, or recreational development, if applicable. Where existing infrastructure is insufficient, describe how existing infrastructure can feasibly and realistically be modified to meet commercial, residential, or recreational development demand; and
  - Proximity to populations and demand for proposed commercial, residential, or recreational development, if applicable.

Where the project area's appraised FMV under the HBU is at least 50% higher[5] than the appraised FMV of its As Is use, the benchmark performance standard has been met and the avoided conversion is considered additional. Once validated, additionality need not be reassessed during the crediting period, except for the regulatory surplus test as specified in section 2.4.1. Refer to section 2.5 for consideration of a conversion probability discount.

[4] https://www.appraisalfoundation.org/imis/TAF/Standards/Appraisal_Standards/Uniform_Standards_of_Professional_Appraisal_Practice/TAF/USPAP.aspx?hkey=62c73d17-9bcf-42b3-a6e4-d4b4b72c098f

[5] Based on the authors' expertise and experience of land management and land use conversion projects, we assume a land worth of 150% the current land worth will drive landowners to implement land use changes.

2.4.2.1 OPPORTUNITY COST FINANICAL BARRIER

In addition to the benchmark performance standard, additionality is bolstered by the carbon project's conservation commitment (section 2.1.1). That is, it is not common practice for landowners to encumber their property with a conservation easement or transfer ownership to other entities, and forego an opportunity to increase value. Carbon revenue helps exceed this opportunity cost financial barrier by compensating for the foregone opportunity.

2.5 CONVERSION PROBABILITY DISCOUNT

The probability of baseline land conversion activities occurring is assumed to be 100%, resulting in no discount applied to the calculation of ERTs ($CPD = 0$), where one of the following conditions are met:

- The temporal land conversion rate for the identified baseline land use is based on verifiable conversion planning documentation (section 4.1); or
- The project area's appraised FMV under the HBU is at least 80% higher than the appraised FMV of its As Is use (section 2.4.2).

Where the temporal land conversion rate for the identified baseline land use is based on the default rates defined in Table 1, and where the project area's appraised FMV under the HBU is less than 80% higher than the appraised FMV of its As Is use, the conversion probability discount (CPD) is computed by the following equation:[6]

Equation 1

$$\textbf{if } \left[(\Delta C_{P,t} - \Delta C_{BSL,t} - LK_t) \times (1 - UNC_{DED,t})\right] \leq 0 \textbf{ then } CPD = 0$$

or

$$\textbf{if } \left[(\Delta C_{P,t} - \Delta C_{BSL,t} - LK_t) \times (1 - UNC_{DED,t})\right] > 0 \textbf{ then } CPD = 1.8 - \left(\frac{FMV_{HBU}}{FMV_{AS\ IS}}\right)$$

WHERE

CPD	Conversion probability discount factor (in %) to be applied in calculation of ERTs for year t.

[6] Adapted from the California Air Resources Board Compliance Offset Protocol - U.S. Forest Projects, June 25, 2015.

$\Delta C_{P,t}$	Change in the with-project carbon stock and GHG emissions (in metric tons CO_2e) during year t.
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) during year t.
LK_t	Total leakage deduction (in metric tons CO_2) for year t.
$UNC_{DED,t}$	Uncertainty deduction (in %) for year t.
FMV_{HBU}	Fair market value (in U.S. dollars) for highest and best use of property as determined by a qualified appraisal.
$FMV_{AS\ IS}$	Fair market value (in U.S. dollars) for current forested, or As Is, condition of property as determined by a qualified appraisal.

2.6 PERMANENCE

Project Proponents commit to a Minimum Project Term of 40 years. Projects must have effective risk mitigation measures in place to compensate fully for any loss of sequestered carbon, whether this occurs through an unforeseen natural disturbance or through a Project Proponent or landowners' choice to discontinue forest carbon project activities. Such mitigation measures can include contributions to the buffer pool, insurance, or other risk mitigation measures approved by ACR.

If using a buffer contribution to mitigate reversals, the Project Proponent must conduct a risk assessment addressing both general and project-specific risk factors. General risk factors include risks such as financial failure, technical failure, management failure, rising land opportunity costs, regulatory and social instability, and natural disturbances. Project-specific risk factors vary by project type but can include land tenure, technical capability and experience of the project developer, fire potential, risks of insect/disease, flooding and extreme weather events, illegal logging potential, and others. If they are using an alternate ACR-approved risk mitigation product, this risk assessment is not applicable.

Project Proponents must conduct their risk assessment using the *ACR Tool for Risk Analysis and Buffer Determination*.[7] The output of this tool is an overall risk category for the project, ex-

[7] Available under the Guidance, Tools & Templates section of the ACR website.

pressed as a percentage, translating into the buffer deduction that must be applied in the calculation of net ERTs (Equations 26 and 27). This deduction must be applied unless the Project Proponent uses another ACR-approved risk mitigation product.

3 STRATIFICATION

If the project activity area is not homogeneous, stratification may be used to improve the modeling of management scenarios and precision of carbon stock estimates. If stratification is used, a stratification standard operating procedures (SOP) document detailing relevant design, inputs, parameters, rules, and techniques must be provided as an attachment to the initial GHG Project Plan for validation. The stratification SOP document should contain information necessary such that the stratification can be examined and duplicated as necessary to provide reasonable assurance of the validity and non-bias of associated techniques. The stratification must be the same for the baseline and with-project scenarios for the estimates of initial stocking levels. However, the number and boundaries of strata may change during the crediting period (*ex post*) as baseline and with-project management practices diverge. For estimation of initial carbon stocks, strata should be defined on the basis of parameters correlated to forest carbon stocking, for example:[8]

- Size and density class
- Age class
- Management regime
- Forest cover types
- Site class
- Soil type or related characteristics

Stratification defined by parameters closely correlated to forest carbon stocks will decrease the likelihood of a required uncertainty deduction (section 7.5). If stratifying, Project Proponents must present in the GHG Project Plan an *ex ante* stratification of the project area. The number and boundaries of the strata defined *ex ante* may change during the crediting period (*ex post*).

The *ex post* stratification may be updated based on relevant changes to with-project scenario management, such as:

- Unexpected disturbances occurring during the crediting period (e.g., wildfire events, pest or disease outbreaks), affecting differently various parts of an originally homogeneous stratum;
- Forest management activities (e.g., planting, thinning, harvesting, coppicing, replanting), implemented in a way that affects the existing stratification; or
- Established strata may be merged if reason for their establishment has disappeared.

[8] This list is not exhaustive and only includes examples of common stratification procedures.

4 BASELINE

4.1 IDENTIFICATION OF BASELINE

Baseline determination is project-specific and represents a legally permissible and operationally feasible scenario converting the project area to the non-forest land use identified as its HBU, following either a schedule set forth in planning documentation or a conservative default schedule.

All legally binding constraints to land conversion (with the exception of easements, deed restrictions, contracts, or other legal mechanisms enacted at project onset per section 2.1.1) must be considered in baseline modeling. These include all existing laws, regulations, legal rulings, deed restrictions, and other relevant regulatory frameworks (such as legally binding terms and conditions associated with the land acquisition, or donor funding restrictions regulating the types of land uses that can occur on the property). Best management practices to protect water, soil stability, and wildlife which apply to land conversion and are published or prescribed by applicable federal, state, or local government agencies are also considered legally binding constraints. If new legal constraints that prohibit land conversion are enacted during a crediting period and prior to the completion of modeled conversion activities, the baseline must be evaluated and remodeled as necessary on a forward-moving basis, respecting these legally binding constraints for the remainder of the crediting period from the time of enforceability.

The qualified appraisal (required per section 2.4.2) identifies the HBU for the project area and thus the baseline alternative land use. The following are applicable baseline non-forest land uses under this methodology:

- Agriculture;
- Mining; or
- Commercial, residential, or recreational development.

The temporal land conversion rate for the identified baseline land use must be based on either:

- Verifiable land conversion planning documentation, containing at minimum the following information:
  - Geographic boundaries of the area planned for conversion. The planning documentation must be relevant to the project area;
  - Timeframe for completion of conversion activities. Conversion is considered complete when the aboveground live biomass and dead wood have been removed to sufficiently allow the alternative land use;
  - The areas affected by conversion activities and the residual forested areas unaffected by conversion actitivities, expressed in acres (or another unit of area or proportion of area);

- Expected cost; and
- Qualifications of the company providing the planning documentation, demonstrating relevant experience with similar projects.

The total conversion impact (percentage of project area converted to non-forest) must be calculated and annualized based on the provided timeframe for completion of conversion activities.

- Where planning documenation is unavailable, the default land conversion rates,[9] based on project area size and defined in Table 1, may be used. The project must demonstrate that the default rates do no conflict with any legal constraints. Recreational development is not eligible for the default conversion rates and must use planning documentation.

Table 1: Default Temporal Land Conversion Rates by Project Area Size

PROJECT AREA SIZE (ACRES)	DURATION OF CONVERSION (YEARS)	ANNUAL CONVERSION RATE (CARBON)
<2,500	1	90%
2,500 to <5,000	2	45%
5,000 to <7,500	3	30%
7,500 to <10,000	4	22.5%
≥ 10,000	5	18%

Projects which aggregate multiple properties or landowners must determine the conversion rates for each group of properties or landowners enrolling simultaneously (i.e. cohort). If applying the default rates, previously enrolled cohorts are not considered in project area size.

The resulting conversion schedule is used to establish baseline carbon stocking levels throughout the crediting period beginning with the initial inventoried tree stocks. The application of annual conversion rates is aspatial; conversion rates are applied directly to the total carbon stored in each relevant and included pool within the project area (above- and belowground live biomass, and, if included, standing and lying dead wood). During baseline conversion activities,

[9] Default conversion rates are based on the authors' expertise and experience with avoided conversion projects. These rates represent a conservative timeframe of conversion (i.e., longer than typically expected to meet landowner income goals) for all project area sizes.

carbon stocks associated with residual live trees are conservatively held static, and growth of residual trees is not required to be projected using an approved growth and yield model.

Where annual conversion rates do not directly align with reporting period length, each pool's projected reduction must be prorated accordingly. When SOC is an included pool, it must not be modeled using the temporal land conversion rates applied to other pools and must instead use the projection methods detailed in Appendix A (section A.2).

This methodology assumes that, following conversion, residual live trees are sparsely distributed along the fringe of development, exhibit stagnant growth due crown exposure and depleted site resources, and are not characteristic of a managed or productive forest. As such, once conversion activities are completed, $\Delta C_{BSL,TREE,t}$ = 0 and $\Delta C_{BSL,DEAD,t}$ = 0, including cases where land conversion results in an incomplete removal of live trees.

Consideration shall be given to a reasonable range of baseline assumptions and the selected assumptions should be feasible and plausible for the duration of the baseline application.

The ISO 14064-2 principle of conservativeness must be applied for the determination of the baseline scenario. In particular, the conservativeness of the baseline is established with reference to the choice of assumptions, parameters, data sources, and key factors so that project emission reductions and removals are more likely to be under-estimated rather than over-estimated, and that reliable results are maintained over a range of probable assumptions. However, using the conservativeness principle does not always imply the use of the "most" conservative choice of assumptions or methodologies.[10]

4.1.1 Baseline Reporting

The GHG Project Plan must include the following baseline metrics:

- A general description of the baseline scenario over the crediting period, including:
  - The HBU (the baseline alternative land use) identified by the qualified appraisal.
  - A description of the conversion schedule and how it was derived.
- A list of any and all legal constraints restricting land use conversion, including:
  - A description of each constraint and its effect upon land use conversion;
  - The geographic extent of each constraint;
  - The governing agency or body associated with each constraint; and
  - A description of how each constraint is considered in the baseline scenario.
- A graph of the projected baseline stocking levels for the following pools:

[10] ISO 14064-2:2006(E)

- Standing live trees;
- Standing dead trees, if included;
- Lying dead wood, if included;
- Harvested wood products; and
- SOC, if included.

4.2 ESTIMATION OF BASELINE EMISSION REDUCTIONS

The following sections and equations are used to compute the baseline net reductions and removals resulting from baseline carbon stock changes, long-term storage in harvested wood products, SOC, and other GHG emissions. This methodology requires the following:

- Baseline stocking levels to be determined for the entire crediting period;
- The change in baseline live tree, dead wood (if included), and SOC carbon stocks (if included) to be computed for each time period, t;
- Baseline carbon stored in wood products 100 years after harvest for each time period, t, to be calculated following section 4.2.4; and
- Baseline greenhouse gas emissions for each time period, t, to be calculated following Equation 5 and section 4.2.6.1.

The following equations are used to construct the baseline stocking levels using the temporal land conversion rate identified per section 4.1, wood products calculations described in section 4.2.4, SOC calculations described in Appendix A, and GHG emission calculations described in 4.2.6.1.

Equation 2

$$\Delta C_{BSL,TREE,t} = (C_{BSL,TREE,t} - C_{BSL,TREE,t-1})$$

WHERE

t	Time in years.
$\Delta C_{BSL,TREE,t}$	Change in the baseline carbon stock in above and below ground live trees (in metric tons CO_2) during year t.

$C_{BSL,TREE,t}$	Baseline carbon stock in above and below ground live trees (in metric tons CO_2) at the end of year t and t-1 signifies the value at the end of the prior year.

Equation 3

$$\Delta C_{BSL,DEAD,t} = (C_{BSL,DEAD,t} - C_{BSL,DEAD,t-1})$$

WHERE

t	Time in years.
$\Delta C_{BSL,DEAD,t}$	Change in the baseline carbon stock in dead wood (in metric tons CO_2) during year t.
$C_{BSL,DEAD,t}$	Baseline carbon stock in dead wood (in metric tons CO_2) at the end of year t and t-1 signifies the value at the end of the prior year.

Any projected reductions in live tree and dead wood carbon stocks due to baseline conversion activities, including harvests and slash burning, must be properly accounted for in Equations 2 and 3. Once conversion activities are completed, $\Delta C_{BSL,TREE,t}$ = 0 and $\Delta C_{BSL,DEAD,t}$ = 0.

Equation 4

$$\Delta C_{BSL,SOC,t} = (C_{BSL,SOC,t} - C_{BSL,SOC,t-1})$$

WHERE

$\Delta C_{BSL,SOC,t}$	Change in the baseline SOC stock (in metric tons CO_2) during year t
$C_{BSL,SOC,t}$	Baseline SOC stock (in metric tons CO_2) at the end of year t and t-1 signifies the value at the end of the prior year (Equation 47). The first reporting period must use the initial SOC stock ($C_{BSL,SOC,0}$; Equation 43) for the value at the end of the prior year (t-1).

NOTE: Please see section 4.2.5 and Appendix A for detailed instructions on SOC calculations.

Equation 5

$$GHG_{BSL,t} = N_2O_{BSL,Fertilizer,t}$$

WHERE

$GHG_{BSL,t}$	Baseline greenhouse gas emissions (in metric tons CO_2e) during year t.
$N_2O_{BSL,Fertilizer,t}$	Baseline N_2O emissions (in metric tons CO_2e) resulting from nitrogen fertilizer application during year t.

NOTE: Please see section 4.2.6.1 for detailed instructions on fertilizer emissions calculations.

Use the following equation to compute the baseline stock change:

Equation 6

$$\Delta C_{BSL,t} = \Delta C_{BSL,TREE,t} + \Delta C_{BSL,DEAD,t} + \Delta C_{BSL,SOC,t} + C_{BSL,HWP,t} - GHG_{BSL,t}$$

WHERE

t	Time in years.
$\Delta C_{BSL,t}$	Change in the baseline carbon stock (in metric tons CO_2) during year t.
$\Delta C_{BSL,TREE,t}$	Change in the baseline carbon stock stored in above and below ground live trees (in metric tons CO_2) during year t.
$\Delta C_{BSL,DEAD,t}$	Change in the baseline carbon stock in dead wood (in metric tons CO_2) during year t.
$\Delta C_{BSL,SOC,t}$	Change in the baseline SOC stock (in metric tons CO_2) during year t.
$C_{BSL,HWP,t}$	Baseline carbon remaining stored in wood products 100 years after harvest (in metric tons CO_2) during year t. See section 4.2.4 for detailed instructions on baseline wood products calculations.
$GHG_{BSL,t}$	Baseline greenhouse gas emissions (in metric tons CO_2e) during year t.

4.2.1 Tree Stocking Level Projections

Baseline tree stocking levels ($C_{BSL,TREE,t}$ and $C_{BSL,DEAD,t}$) must be estimated using the temporal land conversion rate identified per section 4.1, beginning with the initial inventoried tree stocks. With-project tree stocking levels ($C_{P,TREE,t}$ and $C_{P,DEAD,t}$) must be estimated using models of forest management. Modeling must be completed with a peer reviewed forestry model that has been calibrated for use in the project region and approved by ACR. The GHG Project Plan must detail what model is being used and what variants and calibration processes have been selected. All model inputs and outputs (e.g., plot data, model selection, geographic variant, calibration for site-specific conditions, tree list outputs) must be available for inspection by the verifier, and the verifier shall document the methods used in validating the growth and yield model in the validation report.

The following are approved growth and yield models:

- Forest Vegetation Simulator (FVS)

Other appropriate growth models may be used upon approval by ACR and demonstration of the following criteria:

- Peer reviewed in a process involving experts in modeling and biology/forestry/ecology;
- Used only in scenarios relevant to the scope for which the model was developed and evaluated; and
- Parameterized for the specific conditions of the site.

The output of the models must include either projected total aboveground and belowground carbon per acre, volume in live tree biomass, or another appropriate unit by strata in the baseline. Where model projections are output in multi-year increments, the numbers shall be annualized to give stocking values for each year. The same model must be used in the baseline and with-project scenario stocking projections.

If the model output is volume, then this must be converted to biomass and carbon using equations in section 4.2.2. If processing of alternative data on dead wood is necessary, the steps in section 4.2.3 must be used. Estimations of dead wood in the with-project scenario may remain static between measurement events or may be estimated using an approved growth model that predicts dead wood dynamics. Dead wood in the baseline scenario is conservatively held static (not subject to mortality modeling) as the temporal land conversion schedule is applied. If included, standing dead wood must use the same biomass estimation technique (section 4.2.2.1) as live trees.

4.2.2 Tree Carbon Stock Calculation

The mean carbon stock in live tree biomass per unit area is estimated based on field measurements in sample plots.[11] An inventory SOP document must be developed and attached to the GHG Project Plan for validation that describes the inventory process, including the following:

- Sample size;
- Determination of plot locations and numbers;
- Plot size and design, in-field location procedures, and monumentation;
- Whether plots are permanent or temporary;
- Data collected and measurement tools used;
- Detailed measurement procedures such that measurements are repeatable;
- Decay classification of standing dead wood, if applicable;
- Process for recording missing volume, or tree class code as applicable, and how corresponding deductions for unsound wood were applied;
- Biomass estimation technique (section 4.2.2.1);
- Data management systems and processes, including QA/QC procedures; and
- Procedures for updating the inventory, including following harvests or disturbances.

Use or adaptation of inventory SOPs already applied in national forest monitoring systems such as the USDA FIA program,[12] available from published handbooks, or from the IPCC GPG LULUCF[13] is recommended. Plot data used for biomass calculations may not be older than 10 years. Plots may be permanent or temporary and they may have a defined boundary or use variable radius sampling methods.

Biomass for each tree is calculated using one of three estimation techniques (section 4.2.2.1). The Project Proponent must use the same set of equations, diameter at breast height thresholds, and selected biomass components for *ex ante* and *ex post* baseline and with-project estimates.

To ensure accuracy and conservative estimation of the mean aboveground live biomass per unit area within the project area, projects must account for missing portions of the tree in both the *ex ante* and *ex post* baseline and with-project scenarios. Determine missing volume deductions

[11] Other potential sampling techniques are subject to review and approval by ACR prior to use.

[12] Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.1. 2021. U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program.

[13] 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

with cull attribute data (noting defects affecting carbon, not just merchantability) collected during field measurement of sample plots.

The following steps are used to calculate tree biomass:

Step 1 Determine the biomass of each tree based on appropriate volume and/or biomass equations (see section 4.2.2.1).

Step 2 Adjust the calculation of biomass in standing live trees to account for missing portions of the tree (i.e., cavities, broken tops, or other missing wood).

Step 3 Using the sum of the selected biomass components for individual trees, determine the per plot estimate of total tree biomass for each plot.

Step 4 Determine the tree biomass estimate for each stratum by calculating a mean biomass per acre estimate from plot level biomass derived in Step 3 multiplied by the number acres in the stratum.

Step 5 Determine total project carbon (in metric tons CO_2) by summing the biomass of each stratum for the project area and converting biomass to carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

4.2.2.1 BIOMASS ESTIMATION

One of the following biomass estimation techniques must be used:

Option 1 Generalized allometric regression equations for estimating biomass from 10 species groups (Jenkins et al. 2003; Table 4).[14] Appendix A assigns species to species groups. Biomass of above and belowground components must be estimated according to their component ratios (table 6);

Option 2 Biomass algorithms based on the regional volume equations from the USDA Forest Service National Volume Estimator Library,[15] as employed by default in the FVS

[14] Jenkins, Jennifer C.; Chojnacky, David C.; Heath, Linda S.; Birdsey, Richard A. 2003. National scale biomass estimators for United States tree species. Forest Science. 49: 12-35

[15] U.S. Department of Agriculture, Forest Service, National Volume Estimator Library: https://www.fs.fed.us/forestmanagement/products/measurement/volume/nvel/

Fire and Fuels Extension (Rebain et al. 2010).[16] The belowground biomass must be estimated using the Jenkins method (option 1 above). The correct variant for the project area must be selected; or

Option 3 Species specific volume and biomass estimators according to geographic region:[17]

Projects outside CA, OR, WA and AK must use the component ratio method described in Appendix K of the FIA Database Description and User Guide.[18] The methods described in Woodall et al. (2011)[19] are used to calculate gross and sound volumes by region and species.[20] Projects located in IA, IL, IN, KS, MI, MO, MN, ND, NE, SD, and WI must calculate sound volume using the equations specified in Table 5 of Appendix A.[21] For other states, gross volume must be converted to sound volume by subtracting rotten and missing volume. Other components, including belowground live and dead biomass, are estimated and adjusted according to Appendix K (Burrill et al. 2021). Aboveground components are summed for total aboveground biomass.

Projects in CA, OR or WA must use regional volume and biomass equations provided by the USDA FIA program. The Project Proponent must first estimate volume using the models and associated coefficients within "Volumetric Equations for California, Oregon, and Washington" (2014).[22] Biomass is then estimated using the equations within "Biomass Equations for California, Oregon, and Washington"

[16] Rebain, Stephanie A. comp. 2010 (revised June 28, 2021). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 407 p.

[17] Adapted from the California Air Resources Board Compliance Offset Protocol - U.S. Forest Projects, June 25, 2015.

[18] Burrill, Elizabeth A.; DiTommaso, Andrea M.; Turner, Jeffery A.; Pugh, Scott A.; Menlove, James; Christiansen, Glenn; Perry, Carol J.; Conkling, Barbara L. 2021. The Forest Inventory and Analysis Database: database description and user guide version 9.0.1 for Phase 2. U.S. Department of Agriculture, Forest Service. Appendix K: Biomass Estimation in the FIADB, K-1–K-8 p.

[19] Woodall, Christopher W.; Heath, Linda S.; Domke, Grant M.; Nichols, Michael C. 2011. Methods and equations for estimating aboveground volume, biomass, and carbon for trees in the U.S. forest inventory, 2010. Gen. Tech. Rep. NRS-88. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.

[20] See the REF_SPECIES table, prepared by the Forest Inventory and Analysis Database, to determine correct coefficients: https://apps.fs.usda.gov/fia/datamart/CSV/REF_SPECIES.zip

[21] See the Sound Cubic Foot Volume Equation Coefficients, found on the Reference documents section of this methodology's website, to determine correct coefficients.

[22] Volume Estimation for the PNW-FIA Integrated Database; 2014. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

(2014).[23] The CA, OR and WA volume models from Woodall et al. (2011) must not be used. Sum the aboveground standing live and aboveground standing dead tree carbon stocks and apply the methods described in Cairns et al. (1997; Table 3)[24] at the plot level to estimate belowground biomass density based on aboveground biomass density in tons per hectare. The live and dead belowground pools may be separated by multiplying the belowground biomass density by each pool's respective proportion of total aboveground biomass. Calculation of belowground biomass must be consistent for both baseline and with-project scenarios.

Projects in AK must use regional biomass equations provided by the USDA FIA program.[25] The AK volume models found in Woodall et al. (2011) must not be used. Sum the aboveground standing live and aboveground standing dead tree carbon stocks and apply the methods described in Cairns et al. (1997) at the plot level to estimate belowground biomass density based on aboveground biomass density in tons per hectare. Calculation of belowground biomass must be consistent for both baseline and with-project scenarios

Note that the same components must be calculated for *ex ante* and *ex post* baseline and with-project estimates.

4.2.3 Dead Wood Calculation

Dead wood included in the methodology comprises two components – standing dead wood (above and belowground) and lying dead wood. Considering the differences in the two components, different sampling and estimation procedures shall be used to calculate the changes in dead wood biomass of the two components.

4.2.3.1 STANDING DEAD WOOD (IF INCLUDED)

Step 1 Standing dead tree biomass shall be measured and estimated using the same criteria, monitoring frequency, and technique used for measuring and estimating

[23] Regional Biomass Equations Used by FIA to Estimate Bole, Bark, and Branches; 2014. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

[24] Cairns, Michael A.; Brown, Sandra; Helmer, Eileen H.; Baumgardner, Greg A. 1997. Root biomass allocation in the world's upland forest. Oecologia. 111: 1-11

[25] Alaska Biomass Equations; 2002. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

biomass of live trees. The decomposed portion that corresponds to the original biomass is discounted in Step 2.

Step 2 Adjust the calculation of carbon to account for missing portions of the tree (i.e., cavities, broken tops, or other missing wood).

Standing dead tree biomass must be adjusted for density reductions and structural loss. Decay classes must be collected during field measurements according to the classification system of the USDA FIA program.[26]

For projects using Options 1 or 2 of 4.2.2.1:

Standing dead tree biomass must be adjusted for density reduction and structural loss using the Domke (2011) method.[27] Density reduction factors shall be based on either the hardwood/softwood default values found in Table 6 of Harmon et al. (2011)[28] or the species-specific values found in Appendix B. This choice must be applied consistently across the with-project and baseline scenarios. When applying density reduction factors from Appendix B and species are not available, Project Proponents must identify an appropriate decay class from the same genus (Appendix D). With either choice, class 5 standing dead wood must receive the density reduction factor for class 4. Structural loss factors for all species are found in Table 2 of Domke et al. (2011) for decay classes 1-5 for top, bark, bole, stump, and roots. If aboveground biomass is estimated without separating into the components specified in Table 2, the structural loss adjustment factor for roots may be used alone.

For projects using Option 3 of 4.2.2.1:

Projects outside AK, CA, OR, and WA: Standing dead tree biomass must be adjusted for density reduction and structural loss using the Domke (2011) method. Species-specific decay class and density reduction factors are found in Appendix B

[26] Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.1. 2021. U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program.

[27] Domke, G.M.; Woodall, C.W.; Smith, J.E. 2011. Accounting for density reduction and structural loss in standing dead trees: Implications for forest biomass and carbon stock estimates in the United States. Carbon Balance and Management. 6:14.

[28] Harmon, M.E.; Woodall, C.W.; Fasth, B.; Sexton, J.; Yatkov, M. 2011. Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species. Res. Pap. NRS-15. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 40 p.

of Harmon et al. (2011). Where species are not found in Appendix B, Project Proponents must identify an appropriate decay class from the same genus (Appendix D). If not possible, use the hardwood/softwood default values found in Table 6 of Harmon et al. (2011). Class 5 standing dead wood must receive the density reduction factor for class 4. Structural loss factors for all species are found in Table 2 of Domke et al. (2011) for decay classes 1-5 for top, bark, bole, stump, and roots.

Projects in AK, CA, OR, and WA: Apply density conversion factors based on decay classes from Harmon et al. (2011).

Step 3 Using the sum of the selected biomass components for individual trees, determine the per plot estimate of total standing dead tree biomass for each plot.

Step 4 Determine the tree biomass estimate for each stratum by calculating a mean biomass per acre estimate from plot level biomass derived in Step 3 multiplied by the number acres in the stratum.

Step 5 Determine total project standing dead carbon (in metric tons CO_2) by summing the biomass of each stratum for the project area and converting biomass to carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

4.2.3.2 LYING DEAD WOOD (IF INCLUDED)

The lying dead wood pool is highly variable, and stocks may or may not increase as the stands age (depending on previous and projected forest management). Where included, the following steps are required:

Step 1 Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996).[29, 30] At least two 50-meter lines (164 ft) are established bisecting each plot and the diameters of the lying dead wood (≥ 10 cm diameter [≥ 3.9 inches]) intersecting the lines are measured.

[29] Harmon, M.E. and J. Sexton. (1996) Guidelines for measurements of wood detritus in forest ecosystems. U.S. LTER Publication No. 20. U.S. LTER Network Office, University of Washington, Seattle, WA, USA.

[30] A variant on the line intersect method is described by Waddell, K.L. 2002. Sampling coarse wood debris for multiple attributes in extensive resource inventories. Ecological Indicators 1: 139-153. This method may be used in place of Steps 1 to 3.

Step 2 The dead wood is assigned to one of the three density states (sound, intermediate and rotten) by species using the 'machete test', as recommended by IPCC GPG LULUCF.[31] The following dead wood density class deductions must be applied to the three decay classes: For Hardwoods, sound – no deduction, intermediate - 0.45, rotten - 0.42; for Softwoods, sound – no deduction, intermediate - 0.71, rotten - 0.45.[32]

Step 3 The volume of lying dead wood per unit area is calculated using the equation (Warren and Olsen 1964)[33] as modified by Van Wagner (1968)[34] separately for each density class.

Equation 7

$$V_{LDW,DC} = \pi^2 \left(\sum_{n=1}^{N} {D_{n,DC}}^2 \right) \div (8 \times L)$$

WHERE

$V_{LDW,DC}$	Volume (in cubic meters per hectare) of lying dead wood in density class DC per unit area
$D_{n,DC}$	Diameter (in cm) of piece number n, of N total pieces in density class DC along the transect
L	Length (in meters) of transect

Step 4 Volume of lying dead wood shall be converted into biomass using the following relationship:

31 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

32 USFS FIA Phase 3 proportions

33 Warren, W.G. and Olsen, P.F. (1964) A line intersect technique for assessing logging waste. Forest Science 10:267-276

34 Van Wagner, C.E. (1968). The line intersect method in forest fuel sampling. Forest Science 14: 20-26

Equation 8

$$B_{LDW} = A \sum_{DC=1}^{3} V_{LDW,DC} \times WD_{DC}$$

WHERE

B_{LDW}	Biomass (in kilograms per hectare) of lying dead wood per unit area
A	Area (in hectares)
$V_{LDW,DC}$	Volume (in cubic meters per hectare) of lying dead wood in density class DC per unit area
WD_{DC}	Basic wood density (in kilograms per cubic meter) of dead wood in the density class — sound (1), intermediate (2), and rotten (3)

Step 5 Determine total project lying dead carbon by summing the biomass of each stratum for the project area and converting biomass to dry metric tons of Carbon by multiplying by 0.5, kilograms to metric tons by dividing by 1000, and finally carbon to CO_2 by multiplying by 3.664.

4.2.4 Harvested Wood Products Calculation

There are five steps required to account for the harvesting of trees and to determine carbon stored in wood products in the baseline and with-project scenarios:[35]

1. Determining the amount of carbon in trees harvested that is delivered to mills (bole without bark).
2. Accounting for mill efficiencies.
3. Estimating the carbon remaining in in-use wood products 100 years after harvest.
4. Estimating the carbon remaining in landfills 100 years after harvest.
5. Summing the carbon remaining in in-use and landfill wood products 100 years after harvest.

[35] Adapted from Appendix C of the California Air Resources Board Compliance Offset Protocol - U.S. Forest Projects, June 25, 2015.

Step 1 DETERMINE THE AMOUNT OF CARBON IN HARVESTED WOOD DELIVERED TO MILLS

The following steps must be followed to determine the amount of carbon in harvested wood if the biomass model does not provide metric tons carbon in the bole, without bark. If it does, skip to step 2.

I. Determine the amount of wood harvested (actual or baseline) that will be delivered to mills, by volume (cubic feet) or by green weight (lbs.), and by species for the current year. In all cases, harvested wood volumes and/or weights must exclude bark.
   A. Baseline harvested wood quantities and species are derived from modeling a baseline harvesting scenario using an approved growth model.
   B. Actual harvested wood volumes and species must be based on verified third party scaling reports, where available. Where not available, documentation must be provided to support the quantity of wood volume harvested.
      i. If actual or baseline harvested wood volumes are reported in units besides cubic feet or green weight, convert to cubic feet using the following conversion factors:

Table 2: Volume Multipliers for Converting Timber and Chip Units to Cubic Feet or Cubic Meters

UNIT	FT^3 FACTOR	M^3 FACTOR
Bone Dry Tons	71.3	2.0
Bone Dry Units	82.5	2.3
Cords	75.0	2.1
Cubic Feet	1.0	0.0
Cubic Meters	35.3	1.0
Cunits-Chips (CCF)	100.0	2.8
Cunits-Roundwood	100.0	2.8
Cunits-Whole tree chip	126.0	3.6
Green tons	31.5	0.9

MBF-Doyle	222.0	6.3
MBF-International 1/4"	146.0	4.1
MBF-Scribner ("C" or "Small")	165.0	4.7
MBF-Scribner ("Large" or "Long")	145.0	4.1
MCF-Thousand Cubic Feet	1000.0	28.3
Oven Dried Tons	75.8	2.1

II. If a volume measurement is used, multiply the cubic foot volume by the appropriate green specific gravity by species from table 5-3a of the USFS Wood Handbook.[36] This results in pounds of biomass with zero moisture content. If a particular species is not listed in the Wood Handbook, it shall be at the verifier's discretion to approve a substitute species. Any substitute species must be consistently applied across the baseline and with-project calculations.

III. If a weight measurement is used, subtract the water weight based on the moisture content of the wood. This results in pounds of biomass with zero moisture content.

IV. Multiply the dry weight values by 0.5 pounds of carbon/pound of wood to compute the total carbon weight.

V. Divide the carbon weight by 2,204.6 pounds/metric ton and multiply by 3.664 to convert to metric tons of CO2. Sum the CO2 for each species into saw log and pulp volumes (if applicable), and then again into softwood species and hardwood species. These values are used in the next step, accounting for mill efficiencies. Please note that the categorization criteria (upper and lower DBH limits) for hardwood/softwood saw log and pulp volumes are to remain the same between the baseline and with-project scenario.

Step 2 ACCOUNT FOR MILL EFFICIENCIES

Multiply the total carbon weight (metric tons of carbon) for each group derived in Step 1 by the mill efficiency identified for the project's mill location(s) in the Wood Product Reference File.[37] This output represents the total carbon transferred into wood products. The remainder (sawdust and other byproducts) of the harvested

[36] Forest Products Laboratory. Wood handbook - Wood as an engineering material. General Technical Report FPL-GTR-190. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory: 508 p. 2010.

[37] Found on the Reference documents section of this methodology's website.

carbon is considered to be immediately emitted to the atmosphere for accounting purposes in this methodology.

Step 3 ESTIMATE THE CARBON STORAGE 100 YEARS AFTER HARVEST IN IN-USE WOOD PRODUCTS

The amount of carbon that will remain stored in in-use wood products for 100 years depends on the rate at which wood products either decay or are sent to landfills. Decay rates depend on the type of wood product that is produced. Thus, in order to account for the decomposition of harvested wood over time, a decay rate is applied to methodology wood products according to their product class. To approximate the climate benefits of carbon storage, this methodology accounts for the amount of carbon stored 100 years after harvest. Thus, decay rates for each wood product class have been converted into "storage factors" in the table below.

Table 3: 100-Year Storage Factors[38]

WOOD PRODUCT CLASS	IN-USE	LANDFILLS
Softwood Lumber	0.234	0.405
Hardwood Lumber	0.064	0.490
Softwood Plywood	0.245	0.400
Oriented Strandboard	0.349	0.347
Non-Structural Panels	0.138	0.454
Miscellaneous Products	0.003	0.518
Paper	0	0.151
Biomass Fuels/Chips	0	0

STEPS TO ESTIMATE CARBON STORAGE IN IN-USE PRODUCTS 100 YEARS AFTER HARVEST

[38] Smith JE, Heath LS, Skog KE, Birdsey RA (2006) Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. In: General Technical Report NE-343 (eds USDA FS), PP. 218. USDA Forest service, Washington, DC, USA.

To determine the carbon storage in in-use wood products after 100 years, the first step is to determine what percentage of a project area's harvest will end up in each wood product class for each species (where applicable), separated into hardwoods and softwoods. This must be done by either:

- Obtaining verifiable supporting documentation indicating the product categories the mill(s) sold for the year in question; or
- If verifiable supporting documentation cannot be obtained, looking up default wood product classes for the project's Supersection, as given in the Wood Product Reference File. A project's Supersection is determined using the GIS shapefiles,[39] for either the lower 48 states or Alaska respectively. Projects spanning multiple Supersections should use a weighted average wood product class distribution.

If breakdowns for wood product classes are not available from either of these sources, classify all wood products as "miscellaneous."

Once the breakdown of in-use wood product categories is determined, use the 100-year storage factors to estimate the amount of carbon stored in in-use wood products 100 years after harvest:

1. Assign a percentage to each product class for hardwoods and softwoods according to mill data or default values for the project.
2. Multiply the total carbon transferred into wood products by the % in each product class
3. Multiply the values for each product class by the storage factor for in-use wood products
4. Sum all of the resulting values to calculate the carbon stored in in-use wood products after 100 years (in units of CO2-equivalent metric tons).

Step 4 ESTIMATE THE CARBON STORAGE 100 YEARS AFTER HARVEST FOR WOOD PRODUCTS IN LANDFILLS

To determine the appropriate value for landfill carbon storage, perform the following steps:

1. Assign a percentage to each product class for hardwoods and softwoods according to mill data or default values for the project.
2. Multiply the total carbon transferred into wood products by the % in each product class.

[39] Wood Product Reference File and Supersection shapefiles are found on the Reference documents section of this methodology's website.

3. Multiply the values for each product class by the storage factor for landfill carbon.
4. Sum all of the resulting values to calculate the carbon stored in landfills after 100 years (in units of CO2-equivalent metric tons).

Step 5 DETERMINE TOTAL CARBON STORAGE IN WOOD PRODUCTS 100 YEARS AFTER HARVEST

The total carbon storage in wood products after 100 years ($C_{BSL,HWP,t}$ or $C_{P,HWP,t}$) for a given harvest volume is the sum of the carbon stored in landfills after 100 years and the carbon stored in in-use wood products after 100 years. These values are used for the calculation of baseline and with-project carbon stock changes in Equations 6 and 16, respectively. The value for the with-project harvested wood products will vary every year depending on the total amount of harvesting that has taken place. The baseline value will vary every year until the point in time when conversion activities are complete, after which the baseline value will be 0.

4.2.5 Soil Organic Carbon (SOC) Calculation

Where the identified baseline land use is agriculture, SOC emissions associated with baseline conversion activities may be optionally included in the determination of ERTs and may be estimated via NRCS gSSURGO data, direct sampling, or a combination thereof.

See Appendix A for detailed instructions and requirements on SOC computations.

4.2.6 Greenhouse Gas (GHG) Emissions Calculation

The only GHG emissions that are accounted for in this methodology are the direct nitrous oxide (N_2O) emissions associated with fertilizer application.

4.2.6.1 AGRICULTURAL FERTILIZER EMISSIONS (IF INCLUDED)

Where the identified baseline land use is agriculture, emissions from fertilizer application may be optionally included in the determination of ERTs. Where included, fertilizer emissions must be accounted for in both the baseline and with-project scenarios, and the following steps and equations[40] are required:

Step 1 Determine the number of acres treated in each scenario. Baseline acres are determined based on the temporal land conversion rate (section 4.1), while with-project acres are determined by monitoring project implementation (section 5.2).

Step 2 Describe each scenario's fertilizer application practices, including the application rate (e.g., lbs./acre/year), type (synthetic or organic), and specific product used. Baseline practices are determined by identifying regional common practice for the soils present within the project area. Soil determination must follow the options laid out in Appendix A (section A.1) or another verifiable approach of similar rigor. Regional common practice must be substantiated by verifiable documentation that includes the rate, type, and specific product. This documentation must be geographically appropriate and applicable at a scale equivalent to that of the project, and it must include at least one of the following:

- Regional surveys (of landowners, commercial farmers, fertilizer companies, or other relevant stakeholders);
- Governmental agency or university extension office reports or data;
- Peer-reviewed literature or other well-established published sources; or
- In the absence of the above sources of information, expert professional opinion.

With-project practices are based on verifiable documentation of practices implemented during the reporting period, including the rate, type and specific product.

Step 3 Calculate the mass of nitrogen associated with synthetic fertilizer application, adjusted for volatilization as NH_3 and NO_X, for each scenario during each time period:

Equation 9

$$F_{SN,t} = \sum_{k}^{K} M_{SN,k,t} \times N_{SN,k} \times (1 - Frac_{SN})$$

WHERE

[40] CDM A/R Methodological Tool, Estimation of direct nitrous oxide emission from nitrogen fertilization. https://cdm.unfccc.int/methodologies/ARmethodologies/tools/ar-am-tool-07-v1.pdf

$F_{SN,t}$	Mass of synthetic fertilizer nitrogen (in metric tons N), net of volatilized NH_3 and NO_X, applied during year t.
$M_{SN,k,t}$	Mass of synthetic fertilizer type k (in metric tons) applied during year t.
$N_{SN,k}$	Nitrogen content of synthetic fertilizer type k (%).
$Frac_{SN}$	Fraction of synthetic fertilizer nitrogen that volatilizes as NH_3 and NO_X. By default, this value is 0.1.[41]
K	Total number of synthetic inputs of type k.

Step 4 Calculate the mass of nitrogen associated with organic fertilizer application, adjusted for volatilization as NH_3 and NO_X, for each scenario during each time period:

Equation 10

$$F_{OG,t} = \sum_{k}^{K} M_{OG,k,t} \times N_{OG,k} \times (1 - Frac_{OG})$$

WHERE

$F_{OG,t}$	Mass of organic fertilizer nitrogen (in metric tons N), net of volatilized NH_3 and NO_X, applied during year t.
$M_{OG,k,t}$	Mass of organic fertilizer type k (in metric tons) applied during year t.
$N_{OG,k}$	Nitrogen content of organic fertilizer type k (%).

[41] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

$\mathbf{Frac_{OG}}$	Fraction of organic fertilizer nitrogen that volatilizes as NH_3 and NO_X. By default, this value is 0.2.[42]
$\mathbf{K}$	Total number of organic inputs of type k.

Step 5 Calculate each scenario's direct nitrous oxide emissions from fertilizer application during each time period by applying the relevant emission factors[43] for each fertilizer type (synthetic or organic) and converting to carbon dioxide equivalents.

Equation 11

$$\mathbf{N_2O_{Fertilizer,t}} = \left[\left(\mathbf{F_{SN,t}} \times \mathbf{EF_{SN}}\right) + \left(\mathbf{F_{OG,t}} \times \mathbf{EF_{OG}}\right)\right] \times \frac{\mathbf{44}}{\mathbf{28}} \times \mathbf{GWP_{N_2O}}$$

WHERE

$N_2O_{Fertilizer,t}$	Direct N_2O emissions (in metric tons CO_2e) resulting from nitrogen fertilizer application during year t.
$F_{SN,t}$	Mass of synthetic fertilizer nitrogen (in metric tons N), net of volatilized NH_3 and NO_X, applied during year t.
$F_{OG,t}$	Mass of organic fertilizer nitrogen (in metric tons N), net of volatilized NH_3 and NO_X, applied during year t.
EF_{SN}	Emission factor for emissions from synthetic fertilizer nitrogen (%). By default, this value is 2.54%.
EF_{OG}	Emission factor for emissions from organic fertilizer nitrogen (%). By default, this value is 2.03%.
$\frac{44}{28}$	Ratio of molecular weights of N_20 to N; MT N_20 (MT N)$^{-1}$

[42] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan.

[43] E. A. Davidson, The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860. Nature Geoscience. 2, 659–662 (2009).

GWP_{N_2O}	Global warming potential (GWP) factor of nitrous oxide (in metric tons CO_2 per metric tons N_2O).[44]

4.3 MONITORING REQUIREMENTS FOR BASELINE RENEWAL

A project's crediting period is the finite length of time for which the baseline scenario is valid and during which a project can generate offsets against its baseline. Once validated for a crediting period, a project's baseline scenario is fixed, unless legal constraints change such that the baseline conversion activities are legally prohibited (per section 4.1). The baseline modeled conversion of forest to non-forest must fully occur within the initial crediting period. Renewed baselines for subsequent crediting periods will be a steady state and result in no emission reductions, and thus only with-project scenario growth will be credited.

A Project Proponent may apply to renew the crediting period by performing the following:

- Re-submitting the GHG Project Plan in compliance with then-current ACR standards and criteria;
- Demonstrating a continued conservation comittment per section 2.1.1. Easements, deed restrictions, and legally binding contracts which limit conversion must be in place until the end of the renewed crediting period;
- Using ACR-approved baseline methods, emission factors, and tools in effect at the time of crediting period renewal; and
- Undergoing validation and verification by an approved validation/verification body.

4.4 ESTIMATION OF BASELINE UNCERTAINTY

It is assumed that the uncertainties associated with the estimates of the various input data are available, either as default values given in IPCC Guidelines,[45] IPCC GPG LULUCF,[46] or estimates based on sound statistical sampling. Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools must be quantified. Indisputably

[44] As reported by the IPCC Assessment Report version currently approved for use by the *ACR Standard*.

[45] IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T., and Tanabe K. (eds). Published: IGES, Japan.

[46] 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

conservative estimates of uncertainty may also be employed, provided they are justified with relevant verifiable literature and approved by ACR.

Stratification and the allocation of sufficient measurement plots can help minimize uncertainty. It is good practice to consider uncertainty at an early stage in project development to identify the highly variable data pools and allow the opportunity to conduct further work to diminish uncertainty. Estimation of uncertainty for each measurements pool and emissions source requires calculation of both the mean and the width of the 90% confidence interval.

Uncertainty in the baseline scenario should be defined as the weighted average uncertainty of each of the included pools. For measured or modeled live tree and dead wood carbon stock estimates use the confidence interval of the input inventory data. Wood products and greenhouse gas emission also use the live tree inventory data. For SOC use either the confidence interval of directly sampled data. or 0% for gSSURGO-derived estimates. Since gSSURGO SOC data is provided without statistical uncertainty, this methodology requires that indisputably conservative estimates are utilized (section A.1.2). The uncertainty in each pool shall be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock.

Therefore,

Equation 12

$$UNC_{BSL,t} = \sqrt{\frac{\left(C_{BSL,TREE,0} \times e_{BSL,TREE,0}{}^{2}\right) + \left(C_{BSL,DEAD,0} \times e_{BSL,DEAD,0}{}^{2}\right) + \left(C_{BSL,SOC,0} \times e_{BSL,SOC,0}{}^{2}\right) + \left(C_{BSL,HWP,t} \times e_{BSL,TREE,0}{}^{2}\right) + \left(GHG_{BSL,t} \times e_{BSL,TREE,0}{}^{2}\right)}{C_{BSL,TREE,0} + C_{BSL,DEAD,0} + C_{BSL,SOC,0} + C_{BSL,HWP,t} + GHG_{BSL,t}}}$$

WHERE

t	Time in years.
$UNC_{BSL,t}$	Percentage uncertainty in the combined carbon stocks in the baseline for year t.
$C_{BSL,TREE,0}$	Baseline carbon stock in above and below ground live trees (in metric tons CO_2) for the initial inventory at year 0.
$C_{BSL,DEAD,0}$	Baseline carbon stock in dead wood (in metric tons CO_2) for the initial inventory at year 0.
$C_{BSL,SOC,0}$	Baseline SOC stock (in metric tons CO_2) for the initial inventory at year 0.

$C_{BSL,HWP,t}$	Baseline carbon remaining stored in wood products 100 years after harvest (in metric tons of CO_2) during year t.
$GHG_{BSL,t}$	Baseline greenhouse gas emissions (in metric tons CO_2e) during year t.
$e_{BSL,TREE,0}$	Percentage uncertainty expressed as 90% confidence interval of the mean of the carbon stock in above and below ground live trees (in metric tons CO_2) for the initial inventory at year 0.
$e_{BSL,DEAD,0}$	Percentage uncertainty expressed as 90% confidence interval of the mean of the carbon stock in dead wood (in metric tons CO_2) for the initial inventory at year 0.
$e_{BSL,SOC,0}$	Percentage uncertainty expressed as 90% confidence interval of the mean of the directly sampled carbon stock in SOC (in metric tons CO_2) for the initial inventory at year 0. SOC carbon stocks completely derived from gSSURGO data shall use 0%. SOC carbon stocks derived from a combination of direct sampling and gSSURGO data must calculate percentage uncertainty, expressed as 90% confidence interval of the mean, by weighting uncertainty by area, assuming 0% uncertainty for areas using gSSURGO data.

5 WITH-PROJECT SCENARIO

5.1 MONITORING PROJECT IMPLEMENTATION

Information shall be provided, and recorded in the GHG Project Plan, to establish:

- The geographic position of the project boundary is recorded for all areas of land;
- The geographic coordinates of the project boundary (and any stratification inside the boundary) are established, recorded and archived. This may be achieved by field mapping (e.g., GPS) or by using georeferenced spatial data (e.g. maps, GIS datasets, orthorectified aerial photography, or georeferenced remote sensing images), and must result in a GIS dataset provided for validation;
- Professionally accepted principles of forest inventory and management are implemented;
- Stratification procedures are applied and described in a stratification SOP document (section 3); and
- SOPs and QA/QC procedures for forest inventory, including field data collection and data management, are applied and described in an inventory SOP document (section 4.2.2).

5.2 MONITORING OF CARBON STOCKS IN SELECTED POOLS AND EMISSIONS SOURCES

With-project scenario stocks are determined by periodically remeasuring plots (data cannot be older than 10 years) according to the inventory SOP document and modeling carbon stocks to a discrete point in time. For sampling, information shall be provided and recorded in the GHG Project Plan to establish that professionally accepted principles of forest inventory and management are implemented. SOPs and QA/QC procedures for forest inventory, including field data collection and data management, shall be applied. Use or adaptation of inventory SOPs already applied in national forest monitoring systems such as the USDA FIA program,[47] available from published handbooks, or from the IPCC GPG LULUCF[48] is recommended. The inventory SOP

[47] Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.1. 2021. U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program.

[48] 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

document must describe how the project will update the forest inventory data following harvests or disturbances. Mill receipts or other harvest records for with-project harvests occurring within the reporting period must be provided for verification purposes. Where included, emissions from fertilizer application must be monitored during with-project activities, and verifiable documentation of application practices must be provided per section 4.2.6.1.

The 90% statistical confidence interval (CI) of sampling can be no more than ±10% of the mean estimated amount of the combined carbon stock at the project area level.[49] If the Project Proponent cannot meet the targeted ±10% of the mean at 90% confidence, then an uncertainty deduction is applied as determined by section 7.5.

At a minimum, the following data parameters must be monitored:

- Project area;
- Sample plot area;
- Tree species;
- Tree Biomass;
- Wood products volume;
- Fertlizer type(s), application rate(s), and acres treated, if selected; and
- Dead wood pool, if selected.

5.3 ESTIMATION OF WITH-PROJECT REMOVALS

This section describes the steps required to calculate $\Delta C_{P,t}$ (carbon stock change under the with-project scenario; tons CO_2e). This methodology requires:

- Carbon stock levels to be determined at the end of each reporting period, t;
- The change in with-project live tree and dead wood to be computed from the end of the prior reporting period, t-1;
- The reporting period value of with-project carbon stored in wood products 100 years after harvest to be calculated following section 4.2.4; and
- The reporting period value of with-project greenhouse gas emissions to be calculated following Equation 15 and section 4.2.6.1.

[49] For calculating pooled CI of carbon pools across strata, see equations in Barry D. Shiver, Sampling Techniques for Forest Resource Inventory (John Wiley & Sons, Inc, 1996)

The following equations are used to construct the with-project stocking levels using models and forest inventory measurements described in sections 4.2.1 and 4.2.2, respectively:

Equation 13

$$\Delta C_{P,TREE,t} = (C_{P,TREE,t} - C_{P,TREE,t-1})$$

WHERE

t	Time in years.
$\Delta C_{P,TREE,t}$	Change in the with-project carbon stock in above and below ground live trees (in metric tons CO_2) during year t.
$C_{P,TREE,t}$	With-project carbon stock in above and below ground live trees (in metric tons CO_2) at the end of year t and $t-1$ signifies the value at the end of the prior year.

Equation 14

$$\Delta C_{P,DEAD,t} = (C_{P,DEAD,t} - C_{P,DEAD,t-1})$$

WHERE

t	Time in years.
$\Delta C_{P,DEAD,t}$	Change in the with-project carbon stock in dead wood (in metric tons CO_2) during year t.
$C_{P,DEAD,t}$	With-project carbon stock in dead wood (in metric tons CO_2) at the end of year t and $t-1$ signifies the value at the end of the prior year.

Any reductions in carbon stocks due to harvests, disturbances, or slash burning that occurred during the reporting period must be accounted for in Equations 13 and 14.

Equation 15

$$GHG_{P,t} = N_2O_{P,Fertilizer,t}$$

WHERE

$GHG_{P,t}$	With-project greenhouse gas emissions (in metric tons CO_2e) during year t.
$N_2O_{P,Fertilizer,t}$	With-project N_2O emissions (in metric tons CO_2e) resulting from nitrogen fertilizer application during year t.
NOTE: Please see section 4.2.6.1 for detailed instructions on fertilizer emissions calculations.	

Use the following equation to compute change in with-project carbon stock:

Equation 16

$$\Delta C_{P,t} = \Delta C_{P,TREE,t} + \Delta C_{P,DEAD,t} + C_{P,HWP,t} - GHG_{P,t}$$

WHERE

t	Time in years.
$\Delta C_{P,t}$	Change in the with-project carbon stock (in metric tons CO_2) during year t.
$\Delta C_{P,TREE,t}$	Change in the with-project carbon stock in above and below ground live trees (in metric tons CO_2) during year t.
$\Delta C_{P,DEAD,t}$	Change in the with-project carbon stock in dead wood (in metric tons CO_2) during year t.
$C_{P,HWP,t}$	With-project carbon remaining stored in wood products 100 years after harvest (in metric tons CO_2) during year t.
$GHG_{P,t}$	With-project greenhouse gas emissions (in metric tons CO_2e) during year t.

5.3.1 Tree Biomass, Dead Wood, Wood Products, and GHG calculations

The Project Proponent must use the same set of equations used in section 4.2.2, 4.2.3, and 4.2.4 to calculate carbon stocks in the with-project scenario. GHG emissions, if applicable, must be accounted for following section 4.2.6.1 based on monitored fertilizer type(s), application rate(s), and acres treated.

5.4 ESTIMATION OF EMISSIONS DUE TO ACTIVITY-SHIFTING LEAKAGE

The avoided conversion to the alternative land use within the project area may increase pressures to convert forestland outside the project area. The emissions resulting from this activity-shifting leakage must be included in the quantification of project benefits. Intensity of land use demand is highly regional, and carbon projects located within certain regions are expected to induce higher rates of activity-shifting leakage than projects located elsewhere. Activity-shifting leakage shall be quantified by applying a discount factor (Equation 17), which conservatively assumes all projects are located within regions of high land use demand.

Equation 17

$$\mathbf{LK_{A-S} = 0.0431}$$

This deduction is applied to the net emission reductions and removals in the calculation of total leakage emissions (Equation 25).

5.5 ESTIMATION OF EMISSIONS DUE TO MARKET LEAKAGE

While land use supply and demand are the primary economic drivers displaced by the carbon project, reductions in wood product outputs may also be compensated by other entities in the marketplace. Those emissions must be included in the quantification of project benefits. Market leakage shall be quantified by applying the appropriate default market leakage discount factor (Equation 18 or 19):

- Where the project consists of a single or multiple small private landowners (each owning less than 5,000 forested acres), the market leakage deduction is 20%.

  Equation 18

  $$\mathbf{LK_{MARKET} = 0.20}$$

- Where the project consists of one or more large private landowners (owning more than 5,000 forested acres) or any non-private landowners, the market leakage deduction is 30%.

Equation 19

$$LK_{MARKET} = 0.30$$

This discount factor is applied to the wood products that would have been produced in the baseline scenario, net of the wood products produced by the with-project scenario, in the calculation of total leakage emissions (Equation 20).

5.6 ESTIMATION OF TOTAL LEAKAGE EMISSIONS

Estimations of activity-shifting and market leakage shall be combined into a total leakage deduction (Equation 20) to be applied within the calculation of ERTs (Equation 25). Leakage is conservatively excluded from quantification if it is negative.

Equation 20

$$\text{if } (\Delta C_{P,t} - \Delta C_{BSL,t}) \leq 0, \text{ then } LK_t = 0$$

or

$$\text{if } (\Delta C_{P,t} - \Delta C_{BSL,t}) > 0 \text{ and } (C_{P,HWP,t} - C_{BSL,HWP,t}) > 0, \text{ then } LK_t = (\Delta C_{P,t} - \Delta C_{BSL,t}) \times LK_{A-S} + (C_{P,HWP,t} - C_{BSL,HWP,t}) \times LK_{MARKET}$$

or

$$\text{if } (\Delta C_{P,t} - \Delta C_{BSL,t}) > 0 \text{ and } (C_{P,HWP,t} - C_{BSL,HWP,t}) \leq 0, \text{ then } LK_t = (\Delta C_{P,t} - \Delta C_{BSL,t}) \times LK_{A-S}$$

WHERE

t	Time in years.
$\Delta C_{P,t}$	Change in the with-project carbon stock and GHG emissions (in metric tons CO_2e) during year t.
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) during year t.

LK_t	Total leakage deduction (in metric tons CO_2) for year t.
$C_{P,HWP,t}$	With-project carbon remaining stored in wood products 100 years after harvest (in metric tons CO_2) during year t.
$C_{BSL,HWP,t}$	Baseline carbon remaining stored in wood products 100 years after harvest (in metric tons of CO_2) during year t.
LK_{A-S}	Activity-shifting leakage discount factor, in % (section 5.4).
LK_{MARKET}	Market leakage discount factor, in % (section 5.5).

5.7 ESTIMATION OF WITH-PROJECT UNCERTAINTY

Uncertainty in the with-project scenario should be defined as the weighted average error of each of the measurement pools. For modeled results use the confidence interval of the input inventory data. For wood products with measured and documented harvest volume removals use zero as the confidence interval. For estimated wood product removal use the confidence interval of the inventory data. The errors in each pool shall be weighted by the size of the pool so that projects may reasonably target a lower precision level in pools that only form a small proportion of the total stock. There is no uncertainty associated with the project scenario greenhouse gas emissions as fertilizer application is a fully monitored (and not sampled) parameter.

Therefore,

Equation 21

$$UNC_{P,t} = \sqrt{\frac{\left(C_{P,TREE,t} \times e_{P,TREE,t}{}^2\right) + \left(C_{P,DEAD,t} \times e_{P,DEAD,t}{}^2\right) + \left(C_{P,HWP,t} \times e_{P,TREE,t}{}^2\right)}{C_{P,TREE,t} + C_{P,DEAD,t} + C_{P,HWP,t}}}$$

WHERE

t	Time in years.
$\mathbf{UNC_{P,t}}$	Percentage uncertainty in the combined carbon stocks in the project for year t.
$C_{P,TREE,t}$	With-project carbon stock in above and below ground live trees (in metric tons CO_2) at the end of year t.
$C_{P,DEAD,t}$	With-project carbon stock in dead wood (in metric tons CO_2) at the end of year t.
$C_{P,HWP,t}$	With-project carbon remaining stored in wood products 100 years after harvest (in metric tons CO_2) during year t.
$e_{BSL,TREE,t}$	Percentage uncertainty expressed as 90% confidence interval of the mean of the carbon stock in above and below ground live trees (in metric tons CO_2) for the most recent inventory used to estimate stocking at the end of year t.
$e_{BSL,DEAD,t}$	Percentage uncertainty expressed as 90% confidence interval of the mean of the carbon stock in dead wood (in metric tons CO_2) for the most recent inventory used to estimate stocking at the end of year t.

6 EX ANTE ESTIMATION

The Project Proponent must make an *ex ante* calculation of GHG removals and emission reductions for all included sinks and sources for the entire crediting period. These projections must be included in the GHG Project Plan. Project Proponents shall provide estimates of the values of those parameters that are not available before the start of monitoring activities. Project Proponents must retain a conservative approach in making these estimates.

Ex ante projections must be based on best available knowledge of expected with-project management as of the project start date. However, *ex ante* projections do not bind the with-project scenario forest management over the crediting period.

The methods required by this methodology will primarily dictate how *ex ante* projections are calculated. However, when selecting values not dictated by this methodology, *ex ante* projections must be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources;
- National inventory data or default data from IPCC literature that has, whenever possible and necessary, been checked for consistency against available local data specific to the project circumstances; or
- In the absence of the above sources of information, expert opinion may be used to assist with data selection. Experts will often provide a range of data, as well as a most probable value for the data. The rationale for selecting a particular data value must be noted in the GHG Project Plan. For any data provided by experts, the GHG Project Plan shall also record the expert's name, affiliation, and principal qualification as an expert.

When selecting values based on data that is not specific to the project circumstances, such as default data, Project Proponents must select values that will lead to an accurate estimation of net GHG removals and emissions, taking into account uncertainties. If uncertainty is significant, Project Proponents must choose data such that it tends to underestimate, rather than overestimate, net GHG reductions/removals.

7 QA/QC, VALIDATION AND VERIFICATION, AND UNCERTAINTY

7.1 METHODS FOR QUALITY ASSURANCE

An inventory SOP document, including data management systems and processes and QA/QC procedures, must be developed according to the requirements of this methodology (section 4.2.2). These systems, processes, and procedures are subject to validation and subsequent verifications. Use or adaptation of inventory SOPs already applied in national forest monitoring systems such as the USDA FIA program,[50] available from published handbooks, or from the IPCC GPG LULUCF[51] is recommended. A stratification SOP document must also be developed (section 3). Where SOC is an included pool, sampling and stratification SOP documents must be provided (Appendix A).

7.2 METHODS FOR QUALITY CONTROL

Project Proponents shall consider all relevant information that may affect the accounting and quantification of GHG emission reductions/removals, including estimating and accounting for any decreases in carbon pools and/or increases in GHG emission sources. This methodology sets a *de minimis* threshold of 3% of the final calculation of emission reductions and removals. For the purpose of completeness, any decreases in carbon pools and/or increases in GHG emission sources must be included if they exceed the *de minimis* threshold. Any exclusion using the *de minimis* principle shall be justified using fully documented *ex ante* calculations.

[50] Forest Inventory and Analysis national core field guide, volume I: Field data collection procedures for phase 2 plots, version 9.1. 2021. U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis National Program.

[51] 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

7.3 VALIDATION

In accordance with the *ACR Standard* and the *ACR Validation and Verification Standard*, projects must be validated by an ACR-approved validation/verification body prior to its first ERT issuance. Validation may be conducted in conjunction with the project's initial full verification or as a stand-alone validation activity. Projects must be validated within three years of the project start date.

In addition to the scope set out by the *ACR Standard* and the *ACR Validation and Verification Standard* Scope, validation shall assess:

- Conformance with eligibility, applicability, and sustainable forest management requirements;
- Compatibility of the forest management plan with the Montréal Process Criteria (if applicable; section 1.3.1);
- Project geographic boundaries;
- Physical infrastructure, activities, technologies, and processes;
- GHGs, sources, and sinks within the project boundary;
- Project temporal boundary, including the event denoting the project start date;
- Stratification procedures and implementation, if applicable;
- Additionality, including regulatory surplus, the qualified appraisal, and calculation of the conversion probability discount;
- Description of and justification for the baseline scenario, including land conversion planning documentation (if provided), application of the land conversion schedule, and required reporting (section 4.1.1);
- Methodologies and calculations used to generate estimates of baseline and with-project scenario stocks, emission reductions, and removals (including growth and yield model selection and parameterization);
- Procedures for measuring carbon stocks (inventory SOPs);
- Methods for measuring, estimating, and projecting the baseline SOC pool; associated SOP documents; and laboratory results of combustion analysis (if applicable, Appendix A);
- Data management systems and QA/QC procedures;
- Processes for estimating, calculating, and accounting for project-level uncertainty; and
- Roles and responsibilities of participating entities (e.g., Project Proponent, landowner).

The Project Proponent must provide sufficient documentation and data to enable required validation activities.

7.4 VERIFICATION

Projects developed with this methodology must undergo a verification by an ACR-approved validation/verification body at each request for issuance of ERTs. For the initial reporting period, and no less frequently than every five years of reporting thereafter, projects must conduct a full verification including a field visit to the project site. Projects may choose to perform desk-based verifications more frequently in interim years.

In addition to the scope set out by the *ACR Standard* and the *ACR Validation and Verification Standard*, verification shall assess:

- Continued regulatory surplus and conformance with eligibility, applicability, and sustainable forest management requirements;
- Project geographic boundary updates;
- Temporal boundary of the reporting period;
- Stratification updates;
- Calculations used to generate estimates of emissions, emission reductions, and removals;
- Assessment of growth and yield model outputs and projections;
- Original underlying data and documentation as relevant and required to evaluate the GHG assertion;
- Implementation of procedures for measuring carbon stocks (full verifications only; section 7.4.1);
- Implementation of data management systems and QA/QC procedures;
- Results from uncertainty assessments; and
- Updates to roles and responsibilities of participating entities (e.g., Project Proponent, landowner).

The Project Proponent must provide sufficient documentation and data to enable required verification activities.

7.4.1 Resampling of Carbon Stock Measurements

In addition to any other activities needed by the verifier to provide a reasonable level of assurance that the ERT assertion is without material discrepancy, full verification field visits must include a resampling of the carbon stock measurements, to be carried out according to the following specifications:

- The resampled carbon stock (live tree and dead wood, if included) measurements must statistically agree with the project's carbon stock measurements using a two-tailed Student's *t*-test at the 90% confidence interval. If the project's forest inventory is comprised of permanent plots that may be efficiently relocated by the verifier, this test shall be paired. Otherwise, this test shall be unpaired, requiring installation of resampling plots at new locations;

- SOC, if included and directly sampled (section A.1.1.1), must be also resampled. This assessment shall be completed independently of the project's live tree and dead wood (if included) pools with its own *t*-test(s), and shall be completed during the project's validation only. If SOC measurements were collected at the plots used for aboveground biomass, the verifier may elect to use the same resampling plots for all pools, so long as the minimum number of resampling plots for both the aboveground biomass and SOC inventory are met according to Equation 22 below.
- The minimum number of resampling plots, for both the aboveground biomass and SOC pools, shall be determined by calculating the square root of each respective pool's most recent inventory's plot count:

Equation 22

$$n_{RESAMPLE} = \sqrt{n_{INVENTORY,t}}$$

WHERE

t	Time in years.
$n_{RESAMPLE}$	Minimum number of resampling plots.
$n_{INVENTORY,t}$	Total number of sampling plots in the most recent inventory used to estimate stocking at the end of year t.

- If the forest inventory has been stratified, resampling may include the lesser of either 1) five (5) strata selected by the verifier based on a strategic assessment of risk, or 2) fewer than five (5) strata comprising ≥90% of the proportional project carbon stocks. The Student's *t*-test(s) may be performed either independently by strata, or at a consolidated project level, so long as absence of bias and statistical agreement of the *t*-test(s) can be demonstrated; and
- Resampling plot allocation must be based on a strategic assessment of risk, proportional carbon stocking, proportional acreage, or another reasonable and demonstrably non-biased method. Plot selection and resampling sequence must be systematic and non-biased. This might be accomplished by assigning a plot sequence prior to the field visit and progressing through the sequence until both the minimum number of resampling plots and the required statistical agreement are reached.

In addition to the reporting requirements set forth in the *ACR Validation and Verification Standard*, verification reports pertaining to full verifications with field visits must include details about the resampling effort, including how it conformed to the aforementioned specifications.

7.5 CALCULATION OF TOTAL UNCERTAINTY AND UNCERTAINTY DEDUCTION

The following equation must be applied to calculate total uncertainty:

Equation 23

$$UNC_t = \sqrt{\frac{\left(|\Delta C_{BSL,t}| \times UNC_{BSL,t}{}^2\right) + \left(|\Delta C_{P,t}| \times UNC_{P,t}{}^2\right)}{|\Delta C_{BSL,t}| + |\Delta C_{P,t}|}}$$

WHERE

t	Time in years.
UNC_t	Total uncertainty for year t, in %.
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) during year t (section 4.2).
UNC_{BSL}	Baseline uncertainty, in % (section 4.4).
$\Delta C_{P,t}$	Change in the with-project carbon stock and GHG emissions (in metric tons CO_2e) during year t (section 5.3).
$UNC_{P,t}$	With-project uncertainty for year t, in % (section 5.7).

The *ACR Standard* sets a statistical precision requirement of ±10% of the mean with 90% confidence. When total uncertainty is beyond this threshold, an uncertainty deduction affects the calculation of ERTs. The following equation must be applied to calculate an uncertainty deduction ($UNC_{DED,t}$):

Equation 24

$$\text{if } [UNC_t \leq 10\%] \text{ then } UNC_{DED,t} = 0\%$$

or

$$\text{if } [UNC_t > 10\%] \text{ then } UNC_{DED,t} = UNC_t - 10\%$$

WHERE

t	Time in years.
UNC_t	Total uncertainty for year t, in %.
$UNC_{DED,t}$	Uncertainty deduction to be applied in calculation of ERTs for year t, in %.

8 CALCULATION OF ERTS

This section describes the process of determining total and net greenhouse gas emission reductions, removals, and ERTs issued for a reporting period for which a valid verification report has been submitted to ACR. Total greenhouse gas emission reductions and removals ($C_{ACR,t}$) and ERTs are calculated using Equation 25 by adjusting the difference between the with-project carbon stock change, baseline carbon stock change, and leakage deduction for conversion probability and uncertainty.

Equation 25

$$\mathbf{ERT_{RP,t} = C_{ACR,t} = (\Delta C_{P,t} - \Delta C_{BSL,t} - LK_t) \times (1 - CPD) \times (1 - UNC_{DED,t})}$$

WHERE

t	Time in years.
$ERT_{RP,t}$	Total ERTs in reporting period t.
$C_{ACR,t}$	Total greenhouse gas emission reductions/removals (in metric tons CO_2e) in reporting period t.
$\Delta C_{P,t}$	Change in the with-project carbon stock and GHG emissions (in metric tons CO_2e) during year t (section 5.3).
$\Delta C_{BSL,t}$	Change in the baseline carbon stock and GHG emissions (in metric tons CO_2e) during year t (section 4.2).
LK_t	Total leakage deduction (in metric tons CO_2) for year t (section 5.6).
CPD	Conversion probability discount (in %; section 2.5).
$UNC_{DED,t}$	Uncertainty deduction (in %) for year t (section 7.5).

If the Project Proponent has chosen the ACR buffer pool as their risk management option, total ERTs are then multiplied by a non-permanence buffer deduction (Equation 26) to calculate the reporting period buffer contribution. Subtracting this contribution calculates net ERTs (Equation 27).

Equation 26

$$\mathbf{BUF_{RP,t} = ERT_{RP,t} \times BUF}$$

WHERE

$\mathbf{t}$	Time in years.
$\mathbf{BUF_{RP,t}}$	Buffer tons deducted in reporting period $\mathbf{t}$.
$\mathbf{ERT_{RP,t}}$	Total ERTs in reporting period $\mathbf{t}$.
$\mathbf{BUF}$	The non-permanence buffer deduction percentage as calculated in section 2.5. $\mathbf{BUF}$ will be set to zero if an ACR approved insurance product is used.

Equation 27

$$\mathbf{ERT_{NET,RP,t} = ERT_{RP,t} - BUF_{RP,t}}$$

WHERE

$\mathbf{t}$	Time in years.
$\mathbf{ERT_{NET,RP,t}}$	Net ERTs issued in reporting period $\mathbf{t}$.
$\mathbf{ERT_{RP,t}}$	Total ERTs in reporting period $\mathbf{t}$.
$\mathbf{BUF_{RP,t}}$	Buffer tons deducted in reporting period $\mathbf{t}$.

ERTs by vintage shall then be determined by prorating reporting period calendar days within vintage year y (Equation 28), applying the non-permanence buffer deduction (Equation 29) and subtracting ERTs by vintage year from the non-permanence buffer deduction (Equation 30). Buffer pool ERTs will be deposited by vintage, if this is the risk management option the Project Proponent has chosen.

Equation 28

$$\mathbf{ERT_{VIN,y} = ERT_{RP,t} \times (CAL_y / RP_{CAL,t})}$$

WHERE

t	Time in years.
y	Year of ERT vintage.
$ERT_{VIN,y}$	Total ERTs in vintage year y.
$ERT_{RP,t}$	Total ERTs in reporting period t.
CAL_y	Reporting period calendar days within vintage year y.
$RP_{CAL,t}$	Total calendar days within reporting period t.

Equation 29

$$BUF_{VIN,y} = ERT_{VIN,y} \times BUF$$

WHERE

y	Year of ERT vintage.
$BUF_{VIN,y}$	Buffer tons deducted in vintage year t.
$ERT_{VIN,y}$	Total ERTs issued in vintage year t.
BUF	The non-permanence buffer deduction percentage as calculated in section 2.6. BUF will be set to zero if an ACR approved insurance product is used.

Equation 30

$$ERT_{NET,VIN,y} = ERT_{VIN,y} - BUF_{VIN,y}$$

WHERE

y	Year of ERT vintage.
$ERT_{NET,VIN,t}$	Net ERTs issued in vintage year y.

$\mathbf{ERT_{VIN,t}}$	Total ERTs issued in vintage year $\mathbf{y}$.
$\mathbf{BUF_{VIN,t}}$	Buffer tons deducted in vintage year $\mathbf{y}$.

The Project Proponent may elect to distinguish between removals ($\mathrm{REM_{RP,t}}$) and emission reductions ($\mathrm{ER_{RP,t}}$) for a given reporting period with a positive ERT issuance. Removals are calculated by adjusting the with-project carbon stock change for leakage and uncertainty. Emission reductions are calculated as the remaining ERTs, which are the ERTs attributable to the baseline scenario stock change after adjustments. If distinguishing, removals and emission reductions must be allocated to vintage years following the procedure outlined in Equation 28.

Equation 31

$$\mathbf{REM_{RP,t} = \left(\Delta C_{P,t} - LK_t\right) \times (1 - CPD) \times \left(1 - UNC_{DED,t}\right)}$$

WHERE

$\mathbf{t}$	Time in years.
$\mathbf{REM_{RP,t}}$	Total removals in reporting period $\mathbf{t}$.
$\mathbf{\Delta C_{P,t}}$	Change in the with-project carbon stock (in metric tons CO_2e) during year $\mathbf{t}$.
$\mathbf{LK_t}$	Total leakage deduction (in metric tons CO_2) for year $\mathbf{t}$.
$\mathbf{CPD}$	Conversion probability discount (in %).
$\mathbf{UNC_{DED,t}}$	Uncertainty deduction (in %) for year $\mathbf{t}$.

Equation 32

$$\mathbf{ER_{RP,t} = ERT_{RP,t} - REM_{RP,t}}$$

WHERE

$\mathbf{t}$	Time in years.
$\mathbf{ER_{RP,t}}$	Total emission reductions in reporting period $\mathbf{t}$.

$\mathbf{ERT_{RP,t}}$	Total ERTs in reporting period t.
$\mathbf{REM_{RP,t}}$	Total removals in reporting period t.

8.1 REVERSALS AND TERMINATION

Negative project stock change ($C_{ACR,t}$) is a reversal. Reversals must be reported and compensated following requirements detailed in the *ACR AFOLU Carbon Project Reversal Risk Mitigation Agreement* and the *ACR Buffer Pool Terms and Conditions*.[52]

The *ACR Buffer Pool Terms and Conditions* lays out requirements for early project termination due to reversal, for projects whose with-project stocks decrease below baseline levels prior to the end of the minimum project term. Notwithstanding this threshold, projects adhering to this methodology are subject to these requirements and will terminate automatically if a reversal causes the with-project live biomass carbon and dead wood pools, in sum, to decrease below 80% of the initial stocking levels of their respective pools, in sum, at any point prior to the end of the minimum project term.

[52] Available under the Guidance, Tools & Templates section of the ACR website.

APPENDIX A: DETERMINING AND PROJECTING SOC STOCKS

The Soil Organic Carbon (SOC) pool may be optionally included in project accounting where the identified baseline land use is agriculture. This methodology conservatively assumes that the baseline land uses of mining and development have a negligible impact on the SOC pool, which is therefore excluded from such projects. Where included, SOC stocks are conservatively assumed to be in a steady state in the with-project scenario, such that they are fixed over the project life. Because we assume there is no change in the with-project SOC stock during year t, this term is not included in with-project stock change (Equation 16). Credit generation from the SOC pool is due solely to emission reductions associated with the baseline scenario.

Accounting for baseline SOC stock change is comprised of two steps:

- Determining the SOC stocks at the project start date; and
- Projecting the change in baseline SOC stocks due to land conversion activities.

These steps result in estimates of the baseline SOC stock ($C_{BSL,SOC,t}$) for the entire crediting period, to be included in annualized *ex ante* projections, prorated for reporting period length (if applicable), and used in Equation 4.

A.1 DETERMINING INITIAL SOC STOCKS

This methodology distinguishes SOC stocks into organic soils and mineral soils. Organic soils are defined as all non-Folist Histisols and all non-Folistel Histels. All other soils are considered mineral soils under this methodology. The project area shall be stratified into areas consisting of mineral soils and areas consisting of organic soils. No single area can be classified as (and thus contribute to SOC stock estimates of) both mineral and organic soils (i.e., areas of mineral soils and organic soils must each be stratified in a manner as to be spatially independent). The initial SOC stocks in mineral ($SOC_{MINL,0}$) and organic soils ($SOC_{ORG,0}$) shall be distinctly determined by one of the following methods:

Option 1 **Direct sampling**, as further described in section A.1.1. Stratification by mineral and organic soils is required. Projects may choose to further stratify the project area to reduce variability in the sampled SOC estimates. Strata may be defined on the basis of parameters that are key variables for estimating SOC stocks, such as soil taxonomy. However strata are defined, an absence of bias must be demonstrated in application of the stratification procedures and each stratum must be classified as either mineral or organic. The SOC stratification design may be entirely different than the design employed for live and dead biomass (section 3);

Option 2 **NRCS gSSURGO data**, as further described in section A.1.2. Projects must stratify the project area according to gSSURGO map units. Map units may not be further divided and must be classified as either mineral or organic based on its soil order or hydric criterion code; or

Option 3 **A combination thereof**, as further described in section A.1.3. Projects must stratify by gSSURGO map units where they are utilized. Directly sampled areas must be stratified by soil type (mineral or organic) and may be further stratified based on guidelines provided for Option 1.

SOC stratification procedures must be described in an addendum to the stratification SOP document (section 3), to be attached to the GHG Project Plan for validation. This addendum must include the relevant design, inputs, parameters, rules, and techniques used, such that soil stratification is replicable, and it must describe the criteria and processes for classifying mineral and organic soils.

The distinct estimates of SOC stock in mineral ($SOC_{MNL,0}$) and organic soils ($SOC_{ORG,0}$) are summed to calculate total initial SOC stock (i.e., content; $C_{BSL,SOC,0}$) in Equation 43 and are then projected according to their respective loss rates (section A.2).

A.1.1 Direct sampling

Initial SOC stocks may be determined through direct sampling. Soil plots are installed across the project area, and soil cores are collected at each plot to determine both carbon content and bulk density. Measurements must be collected within 3 years of the project start date and are subject to validation.

A.1.1.1 SAMPLING PROCEDURES

SOC sampling procedures must be described in an addendum to the inventory SOP document (section 4.2.2), to be attached to the GHG Project Plan for validation. This addendum must describe the following:

- Sample size;
- Determination of plot locations and numbers;
- Whether SOC plot locations are spatially related to aboveground biomass inventory plot locations;

- In-field location procedures and monumentation;
- Data collected and measurement tools used;
- Detailed measurement procedures such that measurements are repeatable;
- Process for collecting and aggregating multiple cores per plot;
- Names and locations of laborities utilized; and
- Data management systems and processes, including QA/QC procedures.

The sample design must be statistically non-biased and should achieve a desired precision level with respect to the ACR confidence deduction procedures. Plot locations may be determined via systematic or random allocation. SOC measurements may be collected at the same plots used for aboveground biomass, or via a separate allocation. If separately allocated, SOC plots must be permanently monumented to allow relocation for validation purposes. The sampling error(s) and 90% confidence interval resulting from SOC inventory must be computed for use in Equation 12.

SOC must be estimated by collecting soil cores to a depth of 30 centimeters and subsequently analyzing for soil carbon content with standard dry combustion at a commercial, university affiliated, or state affiliated laboratory. SOC sampling procedures must include unbiased methods for addressing soil core sample relocation when the probe will not penetrate to the required 30 centimeter depth (due to a restrictive layer).

The collection and aggregation of at least four SOC cores per plot is required to reduce variability. At least two bulk density cores per plot must also be collected and aggregated. Each aggregate sample must be processed through a 2 millimeter sieve prior to laboratory analysis. Visible root biomass and any surface material must be separated and excluded from all collected samples.

A.1.1.2 CALCULATION OF SOC STOCKS FROM DIRECT SAMPLING

To calculate the estimates of initial SOC content for mineral ($SOC_{MNL,0}$) and organic ($SOC_{ORG,0}$) soils from direct sampling, the average stock per unit area (in metric tons carbon per acre) must first be calculated. The following equation multiplies percent carbon, bulk density, and volume per hectare at 30 centimeters sampling depth (3000), and lastly converts from per hectare to per acre. To estimate the SOC stock per acre for a given set of sample plots within each stratum, use:

Equation 33

$$\mathbf{SOC_{sp,i} = OM_{sample,sp,i} \times BD_{sample,sp,i} \times 3000 \times 0.404686}$$

WHERE

$SOC_{sp,i}$	SOC stock (in metric tons carbon per acre) for sample plot sp within soil stratum i.
$OM_{sample,sp,i}$	Organic matter (in % by weight carbon) of the sample at sample plot sp within soil stratum i as determined in laboratory (fine fraction <2 mm).
$BD_{sample,sp,i}$	Bulk density of fine (<2 mm) fraction of soil (in grams per cubic centimeter) in sample plot sp within soil stratum i as determined in the laboratory.

Next, the mean SOC stock per acre for each stratum must be calculated and converted to tons carbon dioxide per acre.

Equation 34

$$SOC_i = \frac{\sum_{sp=1}^{P_i} SOC_{sp,i}}{P_i} \times 3.664$$

WHERE

SOC_i	Mean SOC content (in metric tons CO_2 per acre) for soil stratum i.
$SOC_{sp,i}$	SOC stock (in metric tons carbon per acre) for sample plot sp within soil stratum i.
P_i	Total number of sample plots (sp) within soil stratum i.

If the project area is comprised of both mineral and organic soils, then Equations 37 and 38 must be performed at least twice. They may be performed further depending on the number of defined soil strata. Stratum estimates must be multiplied by their respective areas and combined according to their soil type (mineral or organic) to calculate the initial SOC stocks for mineral ($SOC_{MNL,0}$) and organic ($SOC_{ORG,0}$) soils.

Equation 35

$$SOC_{MNL,0} = \sum_{i=1}^{x_{MNL}} \left(SOC_{i,MNL} \times acres_{i,MNL}\right)$$

WHERE

$SOC_{MNL,0}$	Initial SOC stock in mineral soils (in metric tons CO_2).
$SOC_{i,MNL}$	Mean SOC stock (in metric tons CO_2 per acre) in mineral soil stratum i as derived from direct sampling.
$acres_{i,MNL}$	Acres in mineral soil stratum i.
x_{MNL}	Total number of mineral soil strata.

Equation 36

$$SOC_{ORG,0} = \sum_{i=1}^{x_{ORG}} \left(SOC_{i,ORG} \times acres_{i,ORG}\right)$$

WHERE

$SOC_{ORG,0}$	Initial SOC stock in organic soils (in metric tons CO_2).
$SOC_{i,ORG}$	Mean SOC stock (in metric tons CO_2 per acre) in organic soil stratum i as derived from direct sampling.
$acres_{i,ORG}$	Acres in organic soil stratum i.
x_{ORG}	Total number of organic soil strata.

A.1.2 NRCS gSSURGO data

Initial SOC stocks may be determined using the Gridded Soil Survey Geographic (gSSURGO) database, maintained by the Natural Resources Conservation Service (NRCS).[53] The project area is mapped in GIS with the geographically appropriate gSSURGO dataset, allowing retrieval of mean soil carbon content and soil type (mineral or organic) for each map unit that comprises

[53] Soil Survey Staff. Gridded Soil Survey Geographic (gSSURGO) Database for the United States of America and the Territories, Commonwealths, and Island Nations served by the USDA-NRCS. United States Department of Agriculture, Natural Resources Conservation Service. Available online at https://gdg.sc.egov.usda.gov/ November 17, 2020 (202007 official release).

the project area. Detailed instructions for data retrieval are available in the gSSURGO SOC Instructions document.[54]

The most recently published gSSURGO data as of the project start date must be used. Data is available for each state or for the whole contiguous United States (CONUS), and either may be used. Null values are presented where data is incomplete or unavailable; these map units and their associated acres must be removed from the gSSURGO-derived stratification and subsequent project SOC accounting. However, these areas are eligible for direct sampling (section A.1.3).

Taxonomic order or hydric criterion codes ("Hydric Criterion" field) are used to classify map units as either mineral or organic soils. A hydric criterion code of 1 denotes a map unit is comprised of organic soils. All Histosols except Folists and all Histels (suborder of Gelisols) except Folistels are classified as organic soils. All other map units shall be classified as mineral soils.

A.1.2.1 CALCULATION OF SOC STOCKS FROM GSSURGO DATA:

To calculate the initial SOC stock estimates for mineral ($SOC_{MNL,0}$) and organic ($SOC_{ORG,0}$) soils from gSSURGO data, each map unit's SOC stock estimate must first be calculated per the following methods[55] (Equations 37-40). SOC estimates must be calculated for each horizon up to 30 centimeters depth for each component within a map unit. To maintain conservatism, a deducted estimate of organic matter must be used. For each horizon (up to 30 centimeters depth) within a given map unit's component, use the following equation to calculate a deducted estimate of organic matter:

Equation 37

$$\mathbf{OM_{DED} = [(om\_r - om\_l) \times 0.75] + om\_l}$$

WHERE

OM_{DED}	Organic matter (in % carbon by weight) deducted for uncertainty.
om_r	Organic matter (in % carbon by weight), representative value, as found in the gSSURGO 'chorizon' table.
om_l	Organic matter (in % by weight carbon), low value, as found in the gSSURGO 'chorizon' table.

[54] Found on the Reference documents section of this methodology's website.

[55] Personal communications with Steve Campbell, Soil Scientist, USDA Natural Resources Conservation Service

The SOC estimate (in kilograms per square meter) for each horizon within 30 centimeters depth is then calculated assuming soil organic matter is approximately 58% carbon by weight.[56] Total volume composed of fragments is accounted for by summing all fragment volumes within the horizon:

Equation 38

$$SOC_{h,cp,i} = [(OM_{DED} \times 0.58)/100] \times dbthirdbar\_r \times \left[\left(100 - \sum fragvol\_r\right)/100\right] \times (hzdepb\_r - hzdept\_r) \times 10$$

WHERE

$SOC_{h,cp,i}$	SOC estimate (in kilograms carbon per square meter) for horizon h within component cp within map unit i.
OM_{DED}	Organic matter (in % by weight carbon) after deduction.
$dbthirdbar\_r$	Oven dry weight of soil material (<2 mm) per unit volume of soil (in grams per cubic centimeter) at a water tension of 1/3 bar, representative value, as found in the gSSURGO 'chorizon' table.
$fragvol\_r$	Percentage volume of the horizon occupied by the 2 mm or larger fraction, on a whole soil base, representative value, as found in the gSSURGO 'chfrags' table.
$hzdepb\_r$	Distance (in cm) from the top of the soil to the base of the soil horizon, representative value, as found in the gSSURGO 'chorizon' table. If the base of the soil horizon exceeds 30 cm, use 30 cm.
$hzdept\_r$	Distance (in cm) from the top of the soil to the upper boundary of the soil horizon, representative value, as found in the gSSURGO 'chorizon' table.

Equation 38 must be performed for each horizon within 30 centimeters depth. The SOC estimates for each horizon within a given component and up to 30 centimeters depth must then be summed to calculate total SOC for the component:

[56] Soil Survey Staff. 2011. Soil Survey Laboratory Information Manual. Soil Survey Investigations Report No. 45, Version 2.0. R. Burt (ed.). U.S. Department of Agriculture, Natural Resources Conservation Service: page 247.

Equation 39

$$\mathbf{SOC_{cp,i} = \sum_{h=1}^{z} SOC_{h,cp,i}}$$

WHERE

$\mathbf{SOC_{cp,i}}$	SOC estimate (in kilograms carbon per square meter; 30 cm depth) for component $\mathbf{cp}$ within map unit $\mathbf{i}$.
$\mathbf{SOC_{h,cp,i}}$	SOC estimate (in kilograms carbon per square meter) for horizon $\mathbf{h}$ within component $\mathbf{cp}$ within map unit $\mathbf{i}$.
$\mathbf{z}$	Total number of horizons within component $\mathbf{cp}$ within map unit $\mathbf{i}$.

Each map unit's SOC estimate is then calculated through a weighted average of its various components, which is converted to metric tons carbon per hectare (10), then to metric tons carbon per acre (0.404686), and finally to metric tons carbon dioxide per acre:

Equation 40

$$\mathbf{SOC_i = \frac{\sum_{cp=1}^{p}\left(SOC_{cp,i} \times comppct\_r\right)}{\sum comppct\_r} \times 10 \times 0.404686 \times 3.664}$$

WHERE

$\mathbf{SOC_i}$	SOC estimate (in metric tons CO_2 per acre; 30 cm depth) for map unit $\mathbf{i}$.
$\mathbf{SOC_{cp,i}}$	SOC estimate (in kilograms per square meter; 30 cm depth) for component $\mathbf{cp}$ within map unit $\mathbf{i}$.
$\mathbf{comppct\_r}$	Percentage area of component $\mathbf{cp}$ within map unit $\mathbf{i}$, representative value, as found in the gSSURGO 'component' table.
$\mathbf{p}$	Total number of components within map unit $\mathbf{i}$.

Lastly, map unit estimates must be multiplied by their respective areas and combined according to their soil type (mineral or organic).

Equation 41

$$SOC_{MNL,0} = \sum_{i=1}^{x_{MNL}} (SOC_{i,MNL} * acres_{i,MNL})$$

WHERE

$SOC_{MNL,0}$	Initial SOC stock in mineral soils (in metric tons CO_2).
$SOC_{i,MNL}$	SOC estimate (in metric tons CO_2 per acre; 30 cm depth) in mineral soil map unit i as derived from gSSURGO data.
$acres_{i,MNL}$	Acres in mineral soil map unit i.
x_{MNL}	Total number of mineral soil map units.

Equation 42

$$SOC_{ORG,0} = \sum_{i=1}^{x_{ORG}} (SOC_{i,ORG} * acres_{i,ORG})$$

WHERE

$SOC_{ORG,0}$	Initial SOC stock in organic soils (in metric tons CO_2).
$SOC_{i,ORG}$	SOC estimate (in metric tons CO_2 per acre; 30 cm depth) in organic soil map unit i as derived from gSSURGO data.
$acres_{i,ORG}$	Acres in organic soil map unit i.
x_{ORG}	Total number of organic soil map units.

A.1.3 Combining Direct Sampling and NRCS gSSURGO Methods

The direct sampling and NRCS gSSURGO SOC estimation methods may be combined in a single project. If so, the soil stratification SOP addendum and geospatial data submissions must clearly distinguish and delineate the stratified geographic extent of each approach. Only one approach (direct sampling or NRCS gSSURGO) may be used per stratum. Following the initial validation and verification, the SOC estimation approach is set for the duration of the crediting period.

All requirements from sections A.1.1 and A.1.2 must be applied to their respective approaches.

A.1.4 Estimation of Total Initial SOC stock

Regardless of the option chosen (A.1), the following equation must be applied to calculate the total initial SOC stock:

Equation 43

$$C_{BSL,SOC,0} = SOC_{MNL,0} + SOC_{ORG,0}$$

WHERE

$C_{BSL,SOC,0}$	Baseline SOC stock (in metric tons CO_2) at project start date (t=0).
$SOC_{MNL,0}$	Initial SOC stock in mineral soils (in metric tons CO_2).
$SOC_{ORG,0}$	Initial SOC stock in organic soils (in metric tons CO_2).

A.2 PROJECTING BASELINE SOC STOCKS

The impacts of forestland conversion to agriculture on mineral and organic soils are vastly different.[57] Therefore, projections of baseline SOC stocks in each soil type shall be treated distinctly by applying unique loss rates to the initial SOC stocks in mineral soils ($SOC_{MNL,0}$) and organic soils ($SOC_{ORG,0}$). Total baseline SOC stock ($C_{BSL,SOC,t}$) is then determined by summing the SOC stocks in each soil type in Equation 47.

To align SOC loss with crediting period length and loss models outlined below, SOC loss of the entire project area is assumed to begin at year 0, regardless of the temporal land conversion rate (section 4.1). Where the total conversion impact (percentage of project area converted to non-forest) is less than 100%, the unconverted proportion must be equivalently withheld from the projected reductions in both organic and mineral SOC stocks.

A.2.1 Mineral Soils

[57] Description of soil organic carbon loss rates for ACR's ACOF methodology v1.0 (2022). Found on the Reference documents section of this methodology's website.

A regression was performed using data from the meta-analysis conducted by Wei et. al. (2014),[58] and a linear model was fitted for SOC loss in temperate forest environments. This empirical model demonstrates that time is a significant ($R2 = 0.41; p < 0.001$) predictor of SOC loss, with SOC on average decreasing by 1.06% per year for a 40-year timeframe. For conservatism, the lower bound of the 90% confidence threshold is used, with a cumulative loss of 60% of SOC stocks in mineral soils being realized over the 40-year crediting period.

To compute the baseline SOC stock in mineral soils, as affected by forestland conversion to agriculture, over the 40-year crediting period, use the following equation:

Equation 44

$$C_{BSL,SOC,MNL,t} = SOC_{MNL,0} \times (1 - [17.68\% + (t \times 1.06\%)])$$

WHERE

t	Time in years (since project start date).
$C_{BSL,SOC,MNL,t}$	Baseline SOC stock in mineral soils (in metric tons CO_2) at the end of year t.
$SOC_{MNL,0}$	Initial SOC stock in mineral soils (in metric tons CO_2) (t=0).

A.2.2 Organic Soils

The unique and rapid weathering processes of organic soils yields a markedly higher loss of SOC than mineral soils when converted to agricultural use. Based on available literature, and our understanding of mineral SOC stock loss following conversion to agriculture (approximately 60% over 40 years), this methodology assumes 90% loss of the initial SOC stock in organic soils over 40 years due to forestland conversion to agriculture.

Project Proponents may use the following table[59] to estimate the loss of baseline SOC stock in organic soils over the 40-year crediting period:

[58] Wei, X., Shao, M., Gale, W. et al. Global pattern of soil carbon losses due to the conversion of forests to agricultural land. Sci Rep 4, 4062 (2014). https://doi.org/10.1038/srep04062

[59] The organic soil loss schedule of Table 2 aligns with the temporal effects observed in the literature, where most carbon loss is realized within the first ten years post-conversion.

Table 4: Organic Soil Loss Schedule

YEARS POST-CONVERSION	ANNUAL LOSS RATE
1-5	9.0%
6-10	5.4%
11-40	0.6%

When using Table 2 to determine the loss rate of organic soils, the cumulative lost amount ($SOC_{LOSS,ORG,t}$) must be calculated by applying the loss rate for the given number of years since the project start date and prorating for reporting period length, if applicable. The baseline SOC stock in organic soils is then computed over the 40-year crediting period using the following equation:

Equation 45

$$C_{BSL,SOC,ORG,t} = SOC_{ORG,0} \times (1 - SOC_{LOSS,ORG,t})$$

WHERE

t	Time in years (since project start date).
$C_{BSL,SOC,ORG,t}$	Baseline SOC stock in organic soils (in metric tons CO_2) at the end of year t.
$SOC_{ORG,0}$	Initial SOC stock in organic soils (in metric tons CO_2) at project start date (t=0).
$SOC_{LOSS,ORG,t}$	Cumulative lost SOC stock in organic soils (%) at the end of year t, as derived from the Table 2.

Alternatively, Project Proponents may choose to estimate the baseline SOC stock in organic soils using a loss rate of 2.25% each year of the 40-year crediting period. This schedule conservatively depletes the organic SOC stock at a slower rate than those observed in the literature. If employing the annual loss rate of 2.25%, use the following equation to compute the baseline SOC stock in organic soils over the 40-year crediting period:

Equation 46

$$C_{BSL,SOC,ORG,t} = SOC_{ORG,0} \times [1 - (t \times 2.25\%)]$$

WHERE

t	Time in years (since project start date).
$C_{BSL,SOC,ORG,t}$	Baseline SOC stock in organic soils (in metric tons CO_2) at the end of year t.
$SOC_{ORG,0}$	Initial SOC stock in organic soils (in metric tons CO_2) (t=0).

A.2.3 Estimation of Total Baseline SOC Stock

The following equation must be applied to calculate total baseline SOC stock throughout the crediting period:

Equation 47

$$C_{BSL,SOC,t} = C_{BSL,SOC,MNL,t} + C_{BSL,SOC,ORG,t}$$

WHERE

t	Time in years.
$C_{BSL,SOC,t}$	Total baseline SOC stock (in metric tons CO_2) at the end of year t.
$C_{BSL,SOC,MNL,t}$	Baseline SOC stock in mineral soils (in metric tons CO_2) at the end of year t.
$C_{BSL,SOC,ORG,t}$	Baseline SOC stock in organic soils (in metric tons CO_2) at the end of year t.

The resulting value is used to calculate the change in baseline SOC stock in Equation 4.

APPENDIX B: CONFIDENTIALITY OF PROPRIETARY INFORMATION

While it remains in the interest of the general public for Project Proponents to be as transparent as possible regarding carbon projects, some may choose to designate certain information as confidential/commercially sensitive. If the Project Proponent chooses to identify information as confidential, they must submit the confidential documentation in separate files marked "Confidential" to ACR and this information shall not be made available to the public. ACR and the validation/verification body shall utilize this information only to the extent required to validate/verify, register the project, and issue ERTs. If the Project Proponent chooses to keep information confidential, a publicly available GHG Project Plan must still be provided to ACR.