American Carbon Registry

Improved Forest Management Methodology

Southwestern Forest Restoration: Reduced Emissions from Decreased Wildfire Severity and Forest Conversion

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A. METHODOLOGY DESCRIPTION

A.1 SCOPE AND DEFINITIONS

This methodology is designed for use in the United States and is applicable to public (municipal, county, state, federal, or other) and Tribal forestlands eligible for management with little or no recent history (within 20 years) of fuel reduction or restoration treatments[1]. This methodology builds upon Improved Forest Management (IFM) methodologies as it calculates emission reductions and removals resulting from a change in public forestland management. The methodology calculates avoided CO_2 emissions from the reduced risk of high severity wildfires in southwestern forests through forest restoration[2]. This approach is only applicable in forests where low/medium-low severity fire is an integral, frequent and natural occurrence, and extensive high-severity fire is not part of the natural disturbance fire regime. Additionally, this methodology accounts for continued CO_2 sequestration in restored forests through retention of forest cover and continued growth of existing forests above what would occur in the baseline scenario. This benefit is derived through preventing the transition of high-to-low carbon dense ecosystem types following severe wildfire (i.e., forests redirected to grasslands or shrublands)[3, 4, 5] .

While this methodology was specifically designed to address landscape-scale restoration treatments in ponderosa pine forests of the southwestern United States, it may eventually be expanded upon to include additional forest types and regions. For the purposes of this methodology, as written at this time, the term "Southwest" refers to the states of Arizona and New Mexico and coinciding with USFS Region 3 [6]. Much of the forest that has been identified as being in need of fuels treatments in order to reduce risk of severe fire exists on federal and state lands. Efforts to restore fire-dependent forests currently face substantial fiscal hurdles [7]. The development of this methodology for generating carbon offsets is intended to help provide supplementary funding necessary to complete landscape scale restoration on these lands, thereby reducing wildfire severity, maintaining forest cover, and stabilizing carbon storage on the landscape.

Biomass modules may be applicable to this methodology and may be developed for future versions of this methodology.

Improved forest management in the project scenario must increase wood extraction through fuels treatments over the baseline scenario, thus leakage of timber activities is not expected. As per the ACR

[1] American Carbon Registry, "The American Carbon Registry Forest Carbon Project Standard" (2.1, 2010)
[2] M. North, M. Hurteau, J. Innes, *Ecol. Appl.* **19**, 1385–1396 (2009)
[3] S. Dore *et al.*, *Glob. Chang. Biol.* **18**, 3171–3185 (2012)
[4] M. Savage, J. N. Mast, *Can. J. For. Resour.* **977**, 967–977 (2005)
[5] J. P. Roccaforte, P. Z. Fulé, W. W. Covington, *Restor. Ecol.* **18**, 820–833 (2010)
[6] http://www.fs.fed.us/foresthealth/regional_offices.shtml

[7] E. Hjerpe, J. Abrams, D. Becker, *Ecol. Restor.* **27**, 169–177 (2009)

Forest Carbon Project Standard if the project scenario increases the yield of wood products or does not reduce the supply produced leakage for IFM projects, the leakage can be considered to be *de minimis*[8].

Table A1.1: Definitions and Acronyms

ACR	American Carbon Registry
Baseline Management	Current common practice management within the project area and surrounding landscape in the absence of project activities.
BMP	Best Management Practices
Burn Probability (percent)	Raster dataset of spatial surfaces for burn probability and the conditional probabilities of six fire intensity levels determined by flame length classes (0 to 2 ft., 2 to 4 ft., 4 to 6 ft., 6 to 8 ft., 8 to 12 ft., and greater than 12 ft.). This dataset was produced using the Large Fire Simulator (FSim) which was developed by Mark Finney at the USDA Forest Service Missoula Fire Lab and was used for modeling fire risk in Wildfire Hazard Potential (see below)
Crediting period	The period of time in which the baseline is considered to be valid and project activities are eligible to generate ERTs.
De minimis	Threshold of 3% of the final calculation of emission reductions or removals.
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 44/12.
CO_2e	Carbon Dioxide equivalent. The amount of CO_2 that would have the same Global Warming Potential (GWP) as other greenhouse gases over a 100-year lifetime using SAR-100 GWP values from the IPCC's fourth assessment report.
EA	Environmental Assessment. An Environmental Assessment (EA) under the National Environmental Policy Act (NEPA) is a concise public document used to predict the environmental consequences (positive or negative) of a plan, policy, program, or project prior to the decision to move forward with the proposed action. The outcome of the EA under NEPA is either a Finding of No Significant Environmental Impact (FONSI) or the preparation of a full Environmental Impact Statement (EIS).
EIS	Environmental Impact Statement. An Environmental Impact Statement (EIS) is a document required by the National Environmental Policy

[8] American Carbon Registry, "The American Carbon Registry Forest Carbon Project Standard" (2.1, 2010),

	Act (NEPA) for certain actions that may, as determined by the EA, significantly affect the quality of the human environment. The EIS document describes the positive and negative environmental effects of a proposed action, usually also lists one or more alternative actions that may be chosen instead of the action described in the EIS, and is used in decision making by federal agencies. The EIS process allows for public and stakeholder engagement. The outcome of the EIS process under NEPA is a federal agency's Record of Decision (ROD).
ERT	Emission Reduction Ton
Ex ante	Prior to project certification.
Ex post	After the event, a measure of past performance.
Fireshed	A baseline stratum based on fire regime, condition class, fire history, fire hazard and risk, and potential wildland fire behavior
Forests, Forestlands	Forestland is defined as land at least 10 percent stocked by trees of any size, and not currently developed for non-forest uses.
Ecological Forest Restoration	Ecological forest restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed in this case specifically to re-introduce natural low severity fire as an ecological force. Restoration focuses on re-establishing the composition, structure, pattern, and ecological processes necessary to facilitate terrestrial and aquatic ecosystem sustainability, resilience, and health under current and future conditions. Restoration treatments can include fuels reduction treatments (see below), prescribed fire (see below) and managed low-severity natural fire, along with other ecological treatments which are not related such as stream bed restoration. For the purpose of this methodology we are only referring to fuels and fire-based treatments, though other aspects of forest restoration are allowed
Fuels Reduction Treatment	Manipulation, including thinning or combustion of fuels to reduce the likelihood of ignition and/or to lessen potential damage and resistance to control. Fuels treatments are a subset of ecological forest restoration.
High Severity Fire	A fire that has marked ecosystem effects, such as complete canopy mortality due to active crown fire or extensive soil heating[9].
IFM	Improved Forest Management (IFM) are activities to reduce GHG emissions and/or enhance GHG removals, implemented on lands designated, sanctioned or approved for forest management [10].
IPCC	Intergovernmental Panel on Climate Change

[9] Keeley, Jon E. "Fire intensity, fire severity and burn severity: a brief review and suggested usage." *International Journal of Wildland Fire* 18.1 (2009): 116-126.

[10] Ibid.

Leakage	Leakage is the displacement of GHG emissions from the project's physical boundaries to locations outside of the project's boundaries as a result of the project action. Leakage includes both activity-shifting and market effects[11].
Low Severity Fire	Typically frequent, surface fuel fires (1-25 yr. MFRI) with few over-story effects due to low fire intensity (e.g. low mortality of dominant vegetation or. lack of active crown fire).
Minimum Project Term	Time period for which project activities must be maintained and monitored through third-party verification.
Mean Fire Return Interval (MFRI)	Arithmetic average of all fire intervals determined in a designated area during a designated time period; the size of the area and the time period must be specified (units = years).
Ponderosa Pine Forest	A forested landscape where ponderosa pine constitutes the dominant species present [12]
Public Lands	Lands owned by the Federal government, state governments, counties, municipalities or other public entities.
Project Area	All applicable lands within the project boundary.
Restoration Unit	A contiguous geographic area, typically between 10,000 and 100,000 acres in size with a cohesive vegetation structure, pattern, spatial arrangement, and potential for destructive fire behavior which needs to be addressed through forest restoration.
Reversal	A release of stored carbon upon which ERTs have been issued such that the atmospheric benefit of the ERTs is not permanent; any event (intentional or unintentional) that reverses the sequestration of carbon in biomass upon which crediting is based.
Ton	A unit of mass equal to 1000 kg.
Tree	A perennial woody plant with a diameter at breast height (1.37 m) >5 cm and a height of greater than 1.3 m.
Tribal Lands	Land or interests in land owned by a tribe or tribes, the title to which is held in trust by the United States, or is subject to a restriction against alienation under the laws of the United States.
Wildfire Hazard Potential	Wildfire hazard potential (WHP) is a raster geospatial product produced by the USDA Forest Service, Fire Modeling Institute[13] that evaluates wildfire risk or prioritization of fuels management needs across very large landscapes (millions of acres). Areas mapped with higher WHP values represent fuels with a higher probability of experiencing torching, crowning, and other forms of extreme fire behavior under conducive weather conditions, based primarily on 2010 landscape conditions.

A.2 APPLICABILITY CONDITIONS

[11] Ibid.

[12] Graham, Russell T., et al. "Effects of thinning and similar stand treatments on fire behavior in western forests." (1999).

[13] Dillon, G. "Wildfire Hazard Potential (WHP) for the conterminous United States (270-m GRID), version 2014 continuous." USDA (2015).

Project developers must demonstrate that the project meets all of the following conditions.

1. Project activities are implemented on public and Tribal forestlands within USFS Region 3
2. Project activities are implemented on forestlands that are eligible for management activities (including: commercial or non-commercial harvesting; and/or prescribed fire activities) with no recent (20 years) fuels reduction treatments.
3. Project activities are implemented on forestlands which are:
    a. Uncharacteristically dense: average stocking must be documented as exceeding the historic range (e.g. pre-1900) of natural variability for the project area forest cover type.
    b. Demonstrate structural characteristics including:
        i. overstocked canopy.
        ii. high ladder fuels component.
        iii. structural distribution skewed toward many small diameter trees.
        iv. contemporary fire regimes outside of the historic (e.g. pre-1900) range of natural variability.
4. Project area must be greater than 10,000 acres and is not required to be contiguous.
5. Public and/or Tribal lands agency must have forest management plans for restoration activities.
6. Restoration must be completed in accordance with applicable land management agencies (e.g. Forest Service, BLM, State) 'Best Management Practices' for protecting water quality and minimizing impacts on threatened and endangered species.
7. Restoration activities that require prescribed burns must adhere to Basic Smoke Management Practices. [14]
8. Restoration activities must result in an improved forest stand, maintaining at least 10% tree canopy cover.
9. Timber harvest in the baseline must not exceed that of the project scenario.
10. Draining or flooding of wetlands is prohibited.
11. Project developer must have documentation of an agreement with the public land agency transferring all carbon offsets generated from the project to the project developer prior to the project start date.
12. The project must maintain an increase in carbon storage in all applicable pools above the baseline condition throughout the crediting period, once ERTs have been issued.

A.3 POOLS AND SOURCES

Project developers are required to monitor increases or decreases in the carbon pools and greenhouse gas sources listed in table A3.1 and A3.2.

Table A3.1: Carbon Pools Considered

Carbon pools	Included / Optional / Excluded	Justification / Explanation of choice

[14] United States Forest Service, Natural Resource Conservation Service, "Basic Smoke Management Practices" (2011).

Above-ground biomass carbon	Included	Major carbon pool subjected to the project activity.
Below-ground biomass carbon	Included	Belowground tree biomass is required for inclusion in the project boundary to capture the effects of fuels treatment and prescribed fire on below-ground stores.
Standing Dead Wood	Included for trees greater than 15 feet in height	Dead wood pools represent a significant medium-lived pool of carbon for Southwest pine forests. In the arid Southwest this pool can be long-lived and is expected to change significantly with warmer and drier conditions. Dead wood pools are affected by both low and high severity fires, but are minimally impacted by fuels treatments.
Lying Dead Wood	Included	Included pool must be estimated in both the baseline and the project.
Harvested Wood Products	Included	Major carbon pool subjected to the project activity. Extracted biomass is counted as a source if not stored in long-term wood products.
Litter / Forest Floor	Excluded	Small carbon pool which exists largely as detritus on the ground surface.
Soil Organic Carbon	Excluded	Soil organic carbon loss can potentially result from combustion of soil (high severity fire) and from large scale mass wasting events following fire (high and low severity fire). Methods to accurately quantify soil organic carbon loss from either are currently not available. Their exclusion is conservative as it reduces the overall emissions associated with the counter factual scenario of high severity fore. Soil carbon pools are therefore excluded.

Table A3.2: Emissions Sources Considered

Gas	Source	Included / excluded	Justification / Explanation of choice
CO_2	Wildfire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent.
	Prescribed Fire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent.

	Fossil Fuel Emissions	Included	All fossil fuel operations emissions associated with management activities, including harvesting, skidding, and hauling. May be considered optional if emissions are *de minimis*. Emission must be calculated using the ACR tool Estimation of Stocks of Carbon Pools and Emissions from Emission Sources [15].
	Slashpile Burning	Included	Included in prescribed burns for project scenario. Biomass re-directed to energy generation is currently counted as a source, see future modules for energy displacement credits.
CH_4	Wildfire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.
	Prescribed Fire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.
	Fossil Fuel Emissions	Included	All fossil fuel operations emissions associated with management activities, including harvesting, skidding, and hauling. May be considered optional if emissions are *de minimis*. Emissions expressed in CO_2 equivalent.
	Slashpile Burning	Included	Included in prescribed burns for project scenario. Biomass re-directed to energy generation is currently counted as a source, see future modules for energy displacement credits. Emissions expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.

[15] American Carbon Registry, "Tool for Estimation of Stocks in Carbon Pools and Emissions from Emission Sources" (1.0, 2011).

N_2O	Wildfire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.
	Prescribed Fire	Included	All stock changes and wildfire emissions are expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.
	Fossil Fuel Emissions	Included	All fossil fuel operations emissions associated with management activities, including harvesting, skidding, and hauling. May be considered optional if emissions are *de minimis*. Emissions expressed in CO_2 equivalent.
	Slashpile Burning	Included	Included in prescribed burns for project scenario. Biomass re-directed to energy generation is currently counted as a source, see future modules for energy displacement credits. Emissions expressed in CO_2 equivalent. May be considered optional if emissions are *de minimis*.

Table A3.3: Leakage Sources Considered

Leakage Source		Included / Optional / Excluded	Justification / Explanation of choice
Activity-Shifting	*Timber Harvesting*	Excluded	Project scenario can create small diameter wood extraction for biomass or timber products where it was previously not institutionally or economically feasible. By ACR Forest Carbon standards this negates leakage of timber extractive activities to alternate locations. Harvesting will be limited by applicable diameter caps, minimum tree per acre

			requirements, and/or maintain forest cover with at least 10% tree stocking.
	Fuelwood	Excluded	Project scenario will have greater timber harvesting activity than baseline.
	Crops	Excluded	Forestlands eligible for this methodology do not produce agricultural crops that could cause activity shifting.
	Livestock	Excluded	Forestlands eligible for this methodology do not limit rangeland activities that could cause activity shifting.
Market Effects	*Timber*	Excluded	Project activities should increase the supply of small diameter wood into markets and do not displace any current timber activities.

A.4 METHODOLOGY SUMMARY

An increase in uncharacteristically severe wildfires is transforming forests in the western United States from a sink to a source of carbon dioxide[16,17]. Wildfires release significant quantities of carbon during high severity fire events, and continue to be a source as debris decompose [18]. High severity fires in Southwest ponderosa pine forests are typically defined by active crown and high mortality of trees, impairing the future storage and sequestration of carbon due to shifts in ecosystem composition from carbon dense forests to lower density grasslands and shrublands[19,20]. The intensity and extent of high severity fires can be reduced through ecological restoration treatments such as fuels treatments and prescribed burns[21]. Fuels treatments reduce surface and ladder fuels by removing small trees. They reduce the risk of active crown fire and encourage the development of less dense forests that can store large amounts of carbon more securely in fewer, but larger trees[22,23]. While the benefits of fuels treatments are known and documented in academic literature, implementation on public lands at the scale necessary to achieve the desired benefits faces fiscal and institutional challenges. This

[16] M. Hurteau, G. W. Koch, B. A. Hungate, *Front. Ecol. Environ.* **6**, 493–498 (2008).
[17] A. L. Westerling, H. G. Hidalgo, D. R. Cayan, T. W. Swetnam, *Science*. **313**, 940–3 (2006).
[18] M. D. Hurteau, M. T. Stoddard, P. Z. Fulé, *Glob. Chang. Biol.* **17**, 1516–1521 (2010).
[19] M. Savage, J. N. Mast, *Can. J. For. Resour.* **977**, 967–977 (2005).
[20] S. Dore *et al.*, *Glob. Chang. Biol.* **14**, 1801–1820 (2008).
[21] M. T. Stoddard, A. J. Sánchez Meador, P. Z. Fulé, J. E. Korb, *For. Ecol. Manage.* (2015).
[22] S. L. Stephens *et al.*, *Bioscience*. **62**, 549–560 (2012).
[23] P. Z. Fulé, J. E. Crouse, J. P. Roccaforte, E. L. Kalies, *For. Ecol. Manage.* **269**, 68–81 (2012).

methodology calculates avoided emissions from reduced wildfire severity and continued sequestration due to the persistence of forested ecosystems.

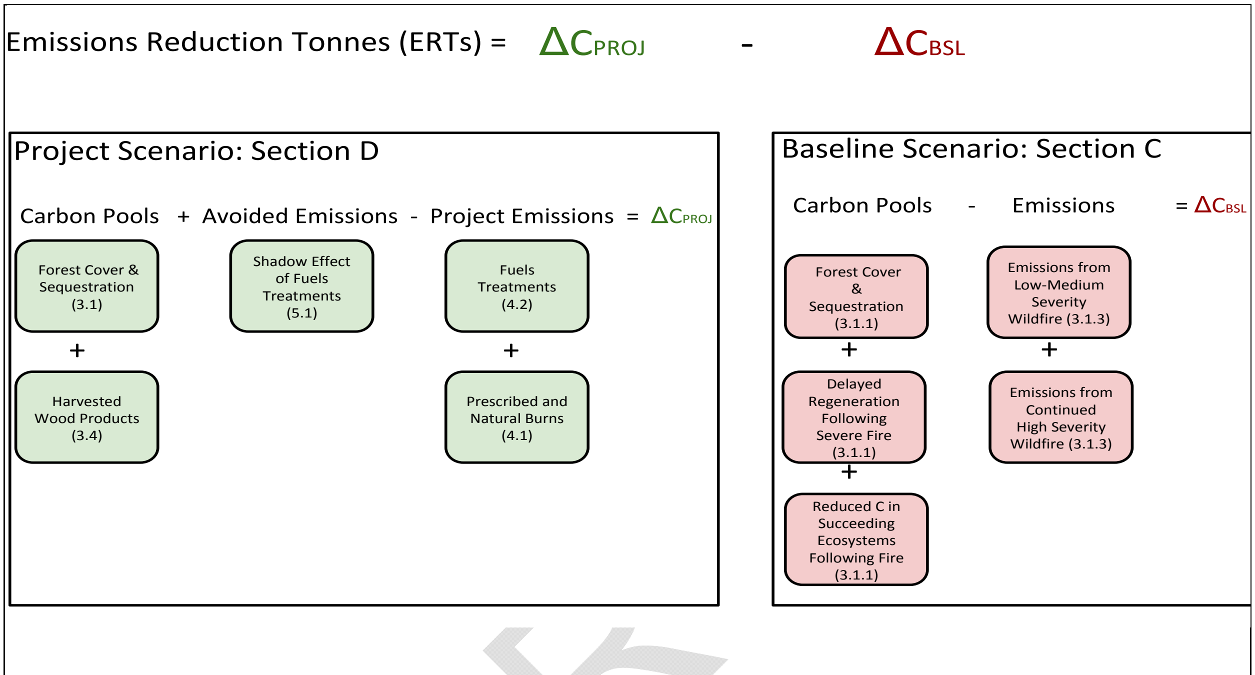


Figure 1: Project Summary Equation of ERT demonstrating the overarching components included in deriving a carbon benefit from Ecological Restoration.

Figure 1 shows the pools and emissions sources accounted for in the baseline and project scenarios. ERTs represent avoided emissions and increased terrestrial carbon storage resulting from project implementation (forest restoration) compared to the counter-factual baseline scenario (no change in current management).

The baseline for this methodology will be project specific and project developers must include the following elements:

- (At project registration) Documentation in the *Purpose and Need* section of a project's NEPA planning documents (Environmental Assessment (EA) or Environmental Impact Statement (EIS)) demonstrating a need for forest restoration or fuels reduction treatments.[24]
- (At project registration) Cite the risk of high-severity fire given current fuel loads within project's NEPA planning documents EA or EIS and propagate risk and area burned over time.
- (At verification) Project above ground carbon losses from a mix of severity classes when they occur.

[24] Council on Environmental Quality, "A Citizen's Guide to the NEPA" (2007).

- (At verification) Modeled carbon stock and sequestration changes in forest and alternate ecosystems which follow wildfire events.

The project scenario combines a calculation of avoided emissions from wildfires (through reduced severity and/or reduced size) during the crediting period and calculates the continued sequestration of treated forests above the baseline of burned forest and regeneration. The project scenario also includes an estimation of the proportion of the high severity sites that are expected to be redirected from high carbon forests to less carbon-dense vegetation types (e.g., grasslands and shrublands). Implementation and maintenance of forest fuels treatments is expected to increase above-ground carbon storage by reducing high severity fire over the long term. All operations emissions associated with treatments must be considered in the project scenario.

Three overarching types of carbon benefits can be realized through conduct of the project activities:

- GHG emissions from wildfires can be reduced by decreasing the severity of wildfires and the corresponding loss in forest carbon stocks.
- Avoided redirection of high carbon to low carbon land cover types (e.g., redirection of ponderosa pine stands to grassland types) as a result of high severity forest fires.
- Potential storage of small diameter wood long-term in harvested wood products.

B. ELIGIBILITY, BOUNDARIES, ADDITIONALITY AND PERMANENCE

B.1 PROOF OF PROJECT ELIGIBILITY

This methodology applies to public and Tribal forestlands in the US which:

1. Are able to document: clear land title and offsets title with the ability to transfer offsets to non-federal owners.
2. Meet all other requirements of the ACR Standard and ACR Forest Carbon Project Standard.
3. Have legally permissible commercial timber harvesting, non-commercial harvesting, and/or prescribed fire on greater than 10,000 acres of forestland.
4. Have documented evidence that the project area qualifies for fuels treatment; evidence must include at a minimum a USFS or BIA prepared restoration plan and associated EA or EIS (or tribal government equivalent) that includes the project area.
5. Can provide documentation of an agreement that gives explicit authorization for the public land agency to enter into a project implementation agreement for the project and transfer of offsets to non-federal owners [25] .
6. Exists within administrative boundary of Region 3 of the U.S. Forest Service.

As per the ACR Forest Carbon Project Standard, IFM projects must remain in forest under improved forest management practices. Proponents must use the U.S. Forest Service Forest Inventory & Analysis (FIA) Program definition to demonstrate that the project area meets the definition of forestland conditions before and after restoration activities. Forestland is defined as land at least 10 percent stocked by trees of any size, and not currently developed for non-forest uses.

Project developers shall assess environmental and community impacts ex-ante in the GHG project proposal. With-project and without-project scenarios must demonstrate a net positive overall difference for the environment and communities. Project developers must evaluate community and environmental impacts through the required NEPA process [26], including the completion of either an Environmental Assessment (EA) or Environmental Impact Statement (EIS) or The Climate, Community and Biodiversity Social Assessment Toolbox [27] which specifically addresses community impacts. Project developers must also submit plans to document (ex-post) environmental and community impacts along with a mitigation plan for any foreseen negative community or environmental impacts and follow EA or EIS guidance.

Proponent must demonstrate that risk of high severity fires on forestlands is outside the range of natural variability and thus requires restoration to reduce fire severity and extent of wildfires. Elevated risk of high severity fire and subsequent need for fuels reduction and/or forest fuels treatments must be documented in EA or EIS documents.

[25] G. Smith, "Forest Offset Projects on Federal Lands" (2012).

[26] Council on Environmental Quality, "A Citizen's Guide to the NEPA" (2007).

[27] M. Richards, "Social and Biodiversity Impact Assement Manual for REDD+ Projects: Part 2 – Social Impact Assesment Toolbox" (2011).

B.2 PROJECT GEOGRAPHIC BOUNDARY

The project geographic boundary will encompass areas which require ecological restoration treatments to reduce wildfire severity and return areas to ecologically functional wildfire regimes. Projects will encompass at least one restoration unit, and will be greater than 10,000 acres in order to achieve a landscape-scale effect capable of reducing fire severity within the project area. Restoration units and sub units are defined and set by public land management agencies. Project area boundaries and restoration units shall be delineated and made available as maps and GIS shapefiles.

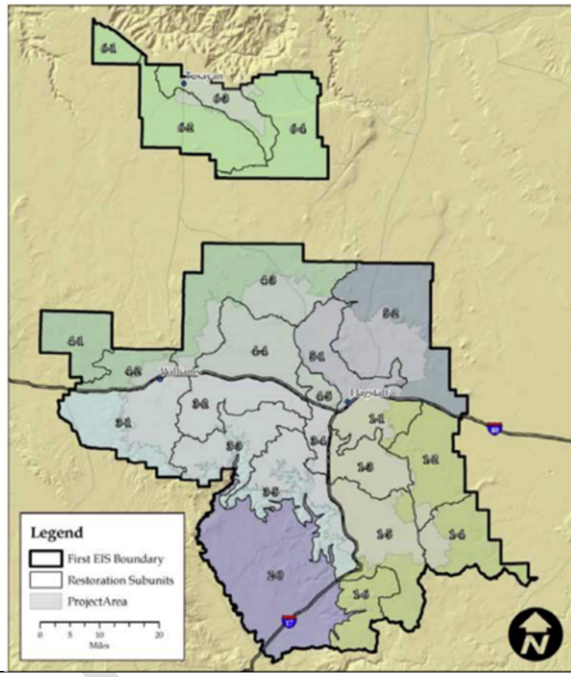


Figure 2. Example of forest restoration units and sub-units from the Four Forest Restoration Initiative (4FRI). Source: Draft EIS Document, 4FRI February 2013.

The project area may be comprised of non-contiguous restoration units. A kml or other GIS file shall be made available in the GHG Project Plan at time of validation, clearly defining the boundaries of restoration units and the project area.

B.3 PROJECT TEMPORAL BOUNDARY

The dates and time frames for the following project events must be defined in the project design document:

- Project crediting period start date.
- Length of the Project Crediting Period, including end date.
- Dates and intervals of project baseline revaluation (baseline revaluation every 20 years).
- Timeline showing when project activities will be implemented.
- Anticipated timeline for monitoring, reporting, and/or verification activities.

Projects with a start date of January 1st, 2000 or later are eligible [28]. The start date marks when the project developer began implementation of land management activities to reduce long-term emissions through forest restoration and fuel reduction treatment activities.

In accordance with the American Carbon Registry's Forest Carbon Project Standard v2.1 for IFM projects, all projects will have a minimum Project Term of 40 years. Crediting periods can be renewed after each 20-year crediting period, assuming project activities are maintained. The maximum project term is one hundred (100) years, a maximum of five crediting periods. The term begins on the start date (not the first or last year of crediting). If the project start date is more than one year before submission of the GHG plan the project developer shall provide evidence that generating forest carbon offsets was seriously considered in the decision to proceed with the project activity. Evidence shall be based on official, legal and/or other agency documentation.

B.4 ADDITIONALITY

Project developers shall pass a project-based additionality test. The project-based additionality test uses a three-pronged approach to demonstrate that the restoration activity would not happen without the carbon-offset project [29].The project developer shall demonstrate in the project design document that the project passes each of the following three tests: 1) a regulatory surplus test that demonstrates that as of the project start date, the project activities exceed currently effective and enforced laws and regulations; 2) a common practice test that shows the project exceeds current forest management practices in the relevant geographic region and forest type; and 3) pass at least one of three possible implementation barriers, which include financial, technological, or institutional.

Project developers must provide transparent and documented evidence, and offer conservative interpretations of this documented evidence, as to how it demonstrates the existence and significance of the identified barriers [30]. Anecdotal evidence can be included, but alone is not sufficient proof of barriers. The type of evidence to be provided may include:

- Relevant legislation, regulatory information or environmental/natural resource management norms, acts or rules.
- Relevant studies undertaken by universities, research institutions, associations, companies, bilateral/multilateral institutions, etc.
- Relevant statistical data from national or international statistics.
- Documentation of relevant market data (e.g. market prices, tariffs, rules).
- Written documentation from the company or institution developing or implementing the IFM project activity or the IFM project developer, such as minutes from board meetings, correspondence, feasibility studies, financial or budgetary information, etc.
- Documents prepared by the project developer, contractors or project partners in the context of the proposed project activity or similar previous project implementations.

[28] American Carbon Registry, "The American Carbon Registry Forest Carbon Project Standard" (2010).
[29] Ibid.
[30] Verified Carbon Standard, "Tool for the Demonstration and Assessment of Additionality in IFM Project Activities, Version 1.0" (2010).

- Written documentation of independent expert judgments from agriculture, forestry and other land-use related Government / Non-Government bodies or individual experts, educational institutions (e.g. universities, technical schools, training centers), professional associations and others.

Details about the requirements for each of the three additionality tests are provided in the sections below.

B.4.1 REGULATORY SURPLUS TEST

The Project developers will show that the project has a start date after January 1st, 2000 and that as of the start date the projects demonstrates regulatory surplus. Regulatory surplus requires documentation that the project is additional to any existing laws, regulations, mandates, statutes, legal rulings, or other regulatory frameworks that directly or indirectly affect GHG emissions associated with a project action or its baseline candidates, and which require technical, performance, or management actions. Voluntary guidelines are not considered in the regulatory surplus test. Offset projects will only be eligible where the management mandates are flexible enough that project activities are not effectively required by the mandates, but where the offset activities contribute to outcomes that are compatible with or enhance mandated uses.

B.4.2 COMMON PRACTICE TEST

The project must pass the common practice additionality test through demonstrating that the proposed project activity exceeds the common practice within the agency, or similar agencies, managing similar forests in the region. Projects initially deemed to go beyond common practice are considered to meet the requirement for the duration of their crediting period. If common practice adoption rates of restoration change during the crediting period, this may make the project non-additional and thus ineligible for renewal, but does not affect its additionality during the current crediting period.

B.4.3 IMPLEMENTATION BARRIER TEST

Project developers must pass one of three possible implementation barrier tests described below. Project developers may demonstrate that their project faces more than one implementation barrier. Implementation barriers include a) financial, b) technological, and c) institutional [31,32].

1. Financial. Financial barriers can include high costs, limited access to capital, or an internal rate of return in the absence of carbon revenues that is lower than the Proponent's established minimum acceptable rate. Financial barriers can also include high risks such as unproven technologies or business models, poor credit rating of project partners, and project failure risk. If electing the financial implementation barrier test Project developers shall provide solid quantitative evidence such as appraisal documents, projected costs and allocated budgets etc.
2. Technological barriers, *inter alia*, and/or a lack of infrastructure for implementation of the technology.

[31] Verified Carbon Standard, "Tool for the Demonstration and Assessment of Additionality in IFM Project Activities, Version 1.0" (2010).
[32] American Carbon Registry, "The American Carbon Registry Forest Carbon Project Standard" (2010).

3. Institutional barriers include. Risk related to changes in government policies or laws; barriers due to prevailing practice; the project activity is the "first of its kind" meaning no project activity of this type is currently operational in the region.

B.5 METHOD FOR ASSURANCE OF PERMANENCE

ACR requires Project developers to commit to a Minimum Project Term of 40 years for project continuance, monitoring and verification [33]. Projects must have effective risk mitigation measures in place to compensate fully for any loss of sequestered carbon whether this occurs through natural disturbance or through a project developer or the public land agency's choice to discontinue forest carbon project activities. Project developers must meet all requirements related to risk and permanence as outlined in the ACR Standard and ACR Forestry Standard.

B.5.1 IDENTIFYING A REVERSAL AND ASSESSING RISK

Permanence refers to the longevity of an emissions reduction/removal and the risk of reversal, i.e. the risk that atmospheric benefit will not be permanent. Fire, disease, pests, and other natural disturbances may cause unintentional reversals. The decision to discontinue project activities constitutes an intentional reversal or to conduct thinning or restoration treatments not included in the original NEPA planning documents,where biomass upon which ERTs have been issued is removed is an intentional reversal. A reversal is any event, intentional or unintentional, where a release of stored carbon upon which ERTs have been issued occurs. Prescribed and natural burns occur in the project scenario as well as removal of forest carbon through restoration activities.

Methods to quantify baseline and project carbon stocks and greenhouse gas emissions are described in detail in sections C and D. Due to the high annual variability in carbon stocks and emissions in restoration units, project carbon is calculated and ERTS issued based on a fit of all observations with a minimum of 5 years of carbon stock data , and are updated upon verification with inventory data. The fit of annual data must maximize R^2 values and must leverage all available project data up to the point of verification. A reversal occurs if the fit used in a subsequent crediting period results in calculated ERT values that are more than 3% lower than issued ERTs calculated from the fit used in a previous crediting period.

Further, given the variation in annual stocks due to fuels treatments and prescribed fire, annual reporting of fire emissions (natural or prescribed) and carbon stocks (including those removed by fuels treatments) to the American Carbon Registry is required of all project developers to assess the potential of an unintentional reversal. Projects which demonstrate an unintentional reversal (e.g. due to high severity wildfire) must conduct a ground inventory and report the results to the American Carbon Registry. Projects which demonstrate fitted carbon stocks below that of the baseline are terminated but available for re-listing. See the American Carbon Registry Forest Carbon Project Standard for additional information[34].

[33] Ibid.

[34] http://americancarbonregistry.org/carbon-accounting/standards-methodologies/forest-carbon-project-standard

B.5.2 INSURING AGAINST REVERSALS

Project developers must conduct their risk assessment using the most current ACR Tool for Risk Analysis and Buffer Determination[35, 36] and/or maintain a buffer pool of 20%, whichever is greater. The buffer pool represents a fraction of overall ERTs which must be held in trust should a reversal in carbon storage occur. The buffer pool deduction must be applied in the calculation of net ERTs (section G1). Effective and complete mitigation of losses provides permanence. Project developers may elect to make the buffer contribution using non-project ERTs, or elect to mitigate the assessed reversal risk using an alternate risk mitigation mechanism, such as insurance approved by ACR in which case the subtraction of offsets for the Buffer Pool (BUF) shall be set equal to zero.

B.5.3 COMPENSATING FOR REVERSALS

In the event that an intentional reversal occurs, the project developer must compensate for the difference in the ERTS that would be calculated from the differing lower bounds of the trend line fits. Please see the ACR Forestry Standard for further guidance on compensation for unintentional and intentional reversals. Unintentional reversals are compensated for from the buffer pool contributions.

[35] Ibid.

[36] http://americancarbonregistry.org/carbon-accounting/tools-templates/acr-risk-tool-v1-0.pdf

C. BASELINE

C.1 IDENTIFICATION OF BASELINE

The baseline scenario represents a counterfactual projection of wildfire, forest cover, and terrestrial carbon storage under current management regimes. The baseline scenario accounts for wildfire risk and severity due to current forest structure, along with the subsequent impacts of varying degrees of wildfire severity including:

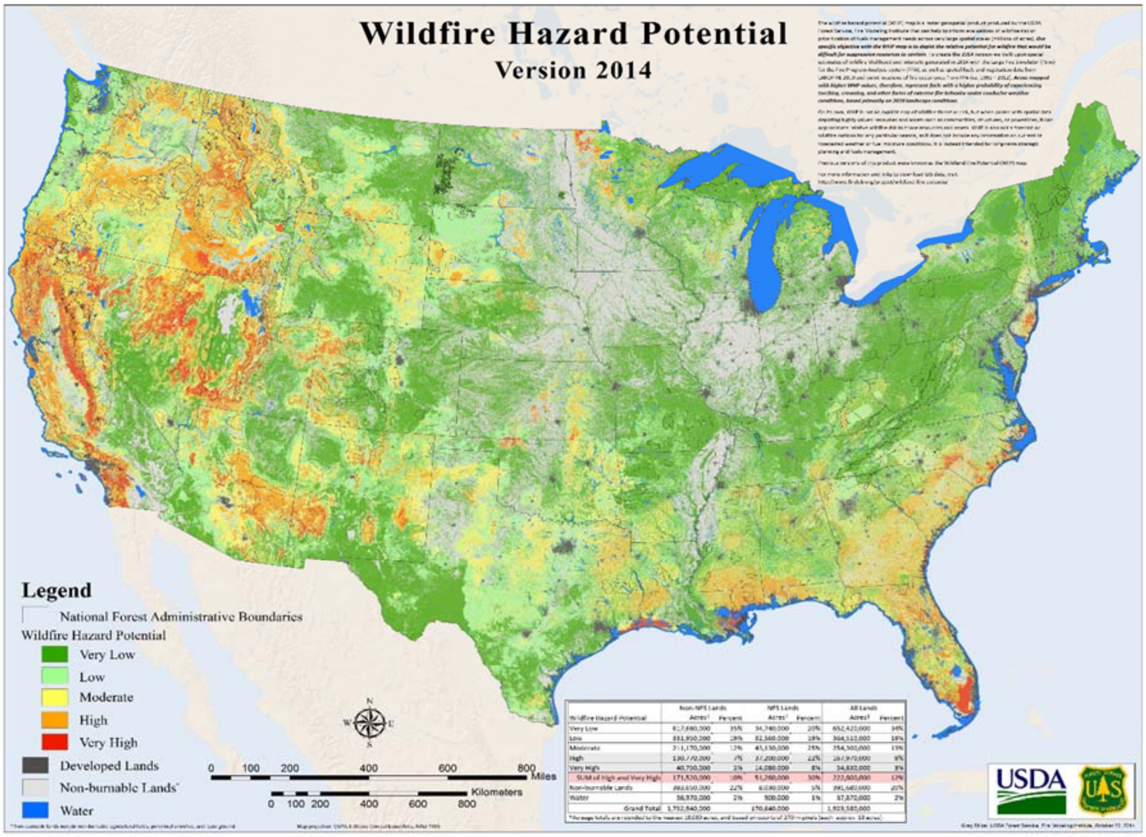
- Delayed regeneration following severe wildfire
- The likelihood of alternate, lower carbon ecosystems succeeding following wildfire (e.g. grasslands or pinyon-juniper savannas)
- The carbon storage and sequestration of alternate ecosystems

Project developers must demonstrate best practices for carbon stock modeling as stated within Region 3 USFS FVS and ClimateFVS manuals, including corrected parameters noted above (see appendix H for additional guidelines).

C.2 BASELINE STRATIFICATION

Within the baseline scenario the project area is stratified into firesheds to improve accuracy and better capture variation in the project area. Firesheds represent areas delineated by:

- Species cover and types (FIA/Landfire dataset)
- Condition class (FIA/Landfire dataset)
- Fire regime
- Fire history
- Classified Wildfire Potential Hazard GIS dataset (moderate or higher, see figure 3), The Severe Fire Potential Map (SFPM) is available at the FRAMES FIRESEV page.



Figures 3. Wildfire Hazard Potential (WHP) for the conterminous United States (270-m GRID), version 2014 continuous [37] Fort Collins, CO

[37] Dillon, G. "Wildfire Hazard Potential (WHP) for the conterminous United States (270-m GRID), version 2014 continuous." USDA (2015).

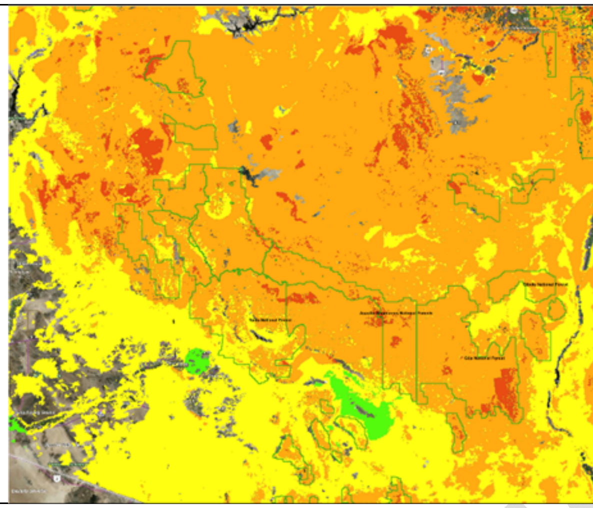


Figure 4. Forest Service Research Data Archive http://dx.doi.org/10.2737/RDS-2015-0047**, subset of WHP illustrating the Four Forest Restoration Initiative(4FRI) example case.**

The combination of these factors result in a fireshed with a cohesive potential wildfire behavior, ignition risk and therefore wildfire hazard. Projects may include multiple fireshed strata within the project boundary. If the project area is not homogeneous, stratification by fireshed must be carried out to improve the precision of forest measurements, model estimates and carbon stock estimates. Different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy and precision of estimates for net GHG emissions reductions or GHG removal by sinks.

C.3 BASELINE NET REMOVALS – EMISSIONS FOR FIXED BASELINES

C.3.1 BASELINE CARBON STOCKS

The following sections outline methods and equations used to construct the baseline carbon stocking levels that incorporate projected changes in forest cover, carbon stocks in section C3.1.1 and removals from wildfire (all intensity levels) emissions using models described in sections C3.1.2 and C3.1.3.

C.3.1.1 PROJECTIONS OF BASELINE CARBON STOCKS

This methodology requires an initial inventory of all stems >5 inches in diameter at breast height, followed by annual baseline stocking levels projected for the entire crediting period of 20 years based on the scenario developed in C1 and inventory measurements. Currently, carbon stock modeling in the baseline must be conducted with Climate FVS, however modeling may be completed with additional peer reviewed forestry model as approved by ACR that have been calibrated for use in the project region and thoroughly vetted. The GHG Plan must detail what model is being used and what variants have been selected. All model inputs and outputs must be available for inspection by the verifier.

Climate FVS must be:

- Used only in scenarios relevant to the scope for which the model was developed and evaluated.

- Parameterized for:
  - Field measurements in the project area.
  - Regeneration delay in accordance with regionally relevant published literature or records within the project area.
  - The likelihood of alternate ecosystems and alternate ecosystem carbon storage following a wildfire event of varying severity.
  - Locally relevant decomposition factors.

The output of the model must include projected volume in total live trees and total standing dead trees, by fireshed in the baseline scenario. Where model projections produce changes in volume over ten year periods, the numbers shall be annualized to give a stock change number for each year. Volume must then be converted to above ground and below ground biomass and carbon using equations in Section D3.1.1. For processing of alternative data on dead wood equations in section D-3.1.2 must be used.

To capture model uncertainty, model runs must be bootstrapped with a 95% confidence interval using a method such as a random seed number (RANSEED), and expressed as Forest Vegetation Simulator Prediction Intervals, or FVSPI [38].

C.3.1.2 BASELINE WILDFIRE PROJECTIONS

The project developer must scale wildfire effects by the probability of fire impacting any given acre in the fireshed over time. **This requires both the modeling of wildfire emissions, and a cumulative density function to scale emissions by the likelihood that they have occurred.**

Forest inventories are used as inputs to the best available and most up to date fire modeling tool (current examples include Fsim, Consume, FlamMap Minimum Travel Time mode), and are used to estimate expected fire size and conditional probability of high-severity fire (e.g., greater than a defined flame length) across the landscape by simulating 10,000 fires per landscape (to model variability of wildfire behavior under both expected and extreme weather scenarios) over decadal time steps based on future climate projections. Project developers must conform to best practices as delineated by the fire modeling tool chosen. For additional information on fire severity as it relates to forest structure please reference Finney et al, 2010, Dillon et al., 2015 [39] [40].

[38] Gregg and Hummel. "Assessing Sampling Uncertainty in FVS Projections Using a Bootstrap Resampling Method." USDA Forest Service Proceedings RMRS (2002).

[39] Finney et al. "Continental-scale simulation of burn probabilities, flame lengths, and fire size distribution for the United States". VI International Conference on Forest Fire Research (2010).

[40] Dillon, G. "Wildfire Hazard Potential (WHP) for the conterminous United States (270-m GRID), version 2014 continuous." USDA (2015).

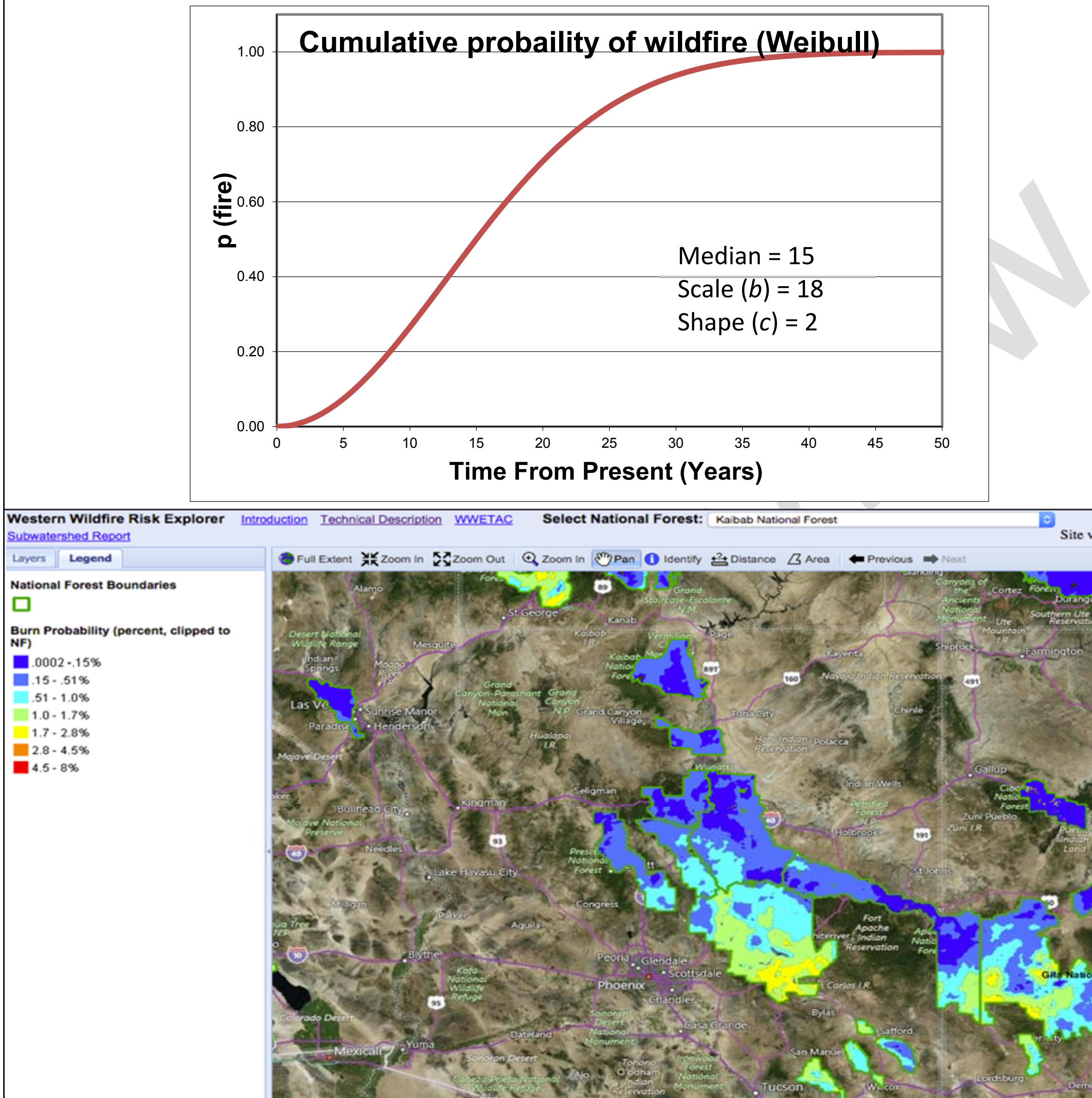


Figure 5. Example of annual burn probability within the Four Forest Restoration project area

Project developers should then apply the Wiebull probability density function or other temporally variable fire probability equation to scale fire effects by the likelihood that they have occurred. The Weibull distribution is frequently used in fire history studies as a model for temporal variation in burn probabilities. Weibull generates a curve which helps assess changes in burn probability annually. For more background on how this distribution relates to fire hazard and fire frequencies see *Fire Ecology of Pacific*

Northwest Forests [41]. In this application, the flexibility of the function describing the Weibull distribution is helpful, being bounded at zero (i.e., negative fire probabilities are impossible) and allowing one to simulate how a mean fire interval may be realized across the landscape, accounting for changes in flammability and so forth.

The "scale" (fire return interval) and "shape" (temporal change in flammability) parameters of the Weibull distribution can be used to control how long and how variable fire intervals tend to be, respectively. Within this project the shape parameter should be set to greater than 1, noting an increase in flammability in years following growth as fuels dry and die. The scale parameter is determined by the annual burn probability percent within the fireshed, or 1/b, where b=the fire return interval of the fireshed and is supported in the scientific literature or fire datasets[42].

The likelihood of fire affecting the project area is then reflected in the cumulative density function of the Weibull distribution, or burn probability (see figure 5), and potential emissions are scaled thereby.

C.3.1.3 DIRECT EMISSIONS

Direct wildfire emissions are defined as the emissions observed or expected for each unit of area on the landscape if that unit burned instantaneously and independently. Direct wildfire emissions can be projected from baseline forest carbon stocks using the latest, validated fire behavior models (see acceptable examples below). Weather for fire at varying flames lengths must be modeled at the 95th percentile.

Examples of appropriate fire emissions models include:

- Fuels and Fires Extension to the Forest Vegetation Simulator (FFE–FVS)
- Fsim
- CONSUME
- FlamMap (v. 5.0)
- FARSITE

Models must be:

- Used in the restoration plan
- Parameterized with field measurements in the area as well as locally applied and validated.
- Peer reviewed in a process involving experts in modeling and fire ecology/forestry/ecology.
- Used only in scenarios relevant to the scope for which the model was developed and evaluated.

Model output should include biomass or carbon stored in above and below ground live wood and standing dead, as well as tC lost via direct emissions from wildfire combustion per fireshed, acre or restoration unit.

41 Agee, James K. *Fire ecology of Pacific Northwest forests*. Island Press, 1996.

42 http://www.mtbs.gov/products.html

C.3.2 CALCULATION OF TOTAL BASELINE CARBON STOCKS

Equation C.1: Annual projected baseline stocking

$$C_{BSL,PROJ_t} = \sum_{i=1}^{n} \left[\left[\left(C_{BSL,LW_{i_t}} + C_{BSL,DW_{i_t}} \right) - \left(W_{WeibullProb_{i_t}} \times W_{DE_{i_t}} \right) \right] \times AW_{fireshed\ i} \right]$$

Where:	
$C_{BSL,PROJ_t}$	represents the sum of all carbon stocks in the baseline scenario projection for year *t including forested, burnt and alternate ecosystems*; tons CO_2e
$C_{BSL,LW_{i_t}}$	represents carbon stocks in baseline live trees for fireshed, restoration unit or sub-unit i, expressed as a modeled 95% confidence interval, year *t*; tons CO_2e
$C_{BSL,DW_{i_t}}$	represents carbon stocks in baseline dead wood pools for restoration unit or sub-unit i, expressed as a modeled 95% confidence interval, year *t*; tons CO_2e
W_{DE}	is the projected potential Direct Emission from wildfire combustion for year *t*, restoration unit or sub-unit *i*; tons CO_2e (see 3.1.3 and equation C-1.1)
$W_{WeibullProb}$	is the cumulative probability of wildfire for year *t* within fireshed i based on the Weibull distribution[5] of fire probability for calculated fire return interval (Eq. C.2
$AW_{fireshed\ i}$	Is the area of the each individual fireshed for which carbon stocks are modeled

$C_{BSL,LW}$, $C_{BSL,DW}$ must be estimated using initial field measurements and models of forest management across the baseline period (section 3.1.1).

Equation C.2: Weibull distribution of fire probability for calculated fire return interval[43].

$$W_{WeibullProb} = (ct^{(c-1)})/b^{c} \times \exp(-(t/b)^{c})$$

Where:	
b	is the scaling parameter annual percent burned, with 1/b representing the fire rotation
c	is the shape parameter (>0), interpreted as a flammability index, with c=1 captures equal flammability with age, and c>1 captures increasing flammability with age (expected within this project)
t	is time
$AW_{fireshed\ i}$	is the area weight of fireshed i, relative to total project area; %

[43] Agee, J. *Fire Ecology of Pacific Northwest Forests*. Island Press (1996).

C.4 MONITORING REQUIREMENTS FOR BASELINE RENEWAL

The 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. The length of the crediting period is project specific and is the time over which conversion is expected to occur. Before entering subsequent crediting periods projects must update direct emissions variables and projections to capture changes in wildfire behavior through time.

To apply to renew the crediting period a project developer must:

- Re-submit the GHG Project Plan in compliance with then-current GHG Program standards and criteria.
- Demonstrate additionality against then-current regulations, common practice and implementation barriers.
- Undergo verification by an approved verifier

Components which are retained from the previous crediting period include:

- Initial inventory stocks
- Baseline wildfire projections

C.5 ESTIMATION OF BASELINE UNCERTAINTY

Procedures including stratification and the allocation of sufficient measurement plots can help reduce uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to diminish uncertainty. This methodology requires a documented sensitivity analysis demonstrating which elements within the baseline scenario (e.g. Fire return interval, initial carbon stocks etc.) contributed to the greatest amount of uncertainty within baseline stock projections, along with documented evidence of incorporating this uncertainty.

Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools should always be quantified. Justified conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources. In this case the uncertainty is assumed to be zero. However, this module provides a procedure to combine uncertainty information and conservative estimates resulting in an overall project scenario uncertainty.

C.5.1 BASELINE UNCERTAINTY CALCULATION

Estimation of uncertainty for pools and emissions sources requires calculation of both the mean and 95% confidence interval. The uncertainty in the baseline scenario should be defined as the square root of the summed errors in each of the measurement pools (equation C-3). For modeled results use the confidence interval of the input inventory data, as well as the confidence interval or the modeled results themselves.

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.

A component of U_{BSL} includes an assessment of uncertainty of direct emissions estimates from baseline wildfires. Two primary assumptions drive uncertainty of wildfire emissions on the landscape: 1) timing of wildfire events; and 2) fire severity as driven by weather conditions at the time of the wildfire. Project developers must model a range of timing of wildfire events (e.g. in project year 1, 10, 20, 40) and weather conditions appropriate to the defined project area to generate a 95% confidence interval as a percentage of the mean expected emissions (equation C-3).

Equation C.3: Baseline Uncertainty

$$\boldsymbol{Uncertainty_{BSL,SS,i}} = \frac{\sqrt{(U_{BSL,SS1,i} \times E_{BSL,SSi,i})^2 + (U_{BSL,SS2,i} \times E_{BSL,SS2,i})^2 + \cdots + (U_{BSL,SSn,i} \times E_{BSL,SSn,i})^2}}{E_{BSL,SSi,i} + E_{BSL,SS2,i} + E_{BSL,SSn,i}}$$

Where:	
$Uncertainty_{BSL,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the baseline case in stratum *i*; %
$U_{BSL,SS,i}$	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline case in stratum *i* (1,2…n represent different carbon pools and/or GHG sources); %
$E_{BSL,SS,i}$	Carbon stock or GHG sources (e.g. trees, dead wood, wildfire emissions) in stratum i (1,2…n represent different carbon pools and/or GHG sources) in the baseline case; t CO2-e
i	1,2,3……. n firesheds

D. WITH-PROJECT SCENARIO

D.1 WITH-PROJECT STRATIFICATION

The project scenario represents proactive forest restoration efforts, which remove excess fuels (reducing potential wildfire severity) through small diameter wood extraction and the reintroduction of low-severity surface fires (i.e. prescribe burns) and allowing natural low-severity fires to burn. The goal is to intercept current wildfire trajectories and restore natural functions of fire, improve forest health, and promote continued forest cover.

Within the project it is expected that forest restoration prescriptions will vary due to heterogeneity in forest density and type. Project developers shall utilize restoration unit boundaries outlined in current Environmental Impact Statement (EIS) documents to improve the precision of carbon stock estimates. Project participants must present in the GHG Plan an ex-ante stratification of restoration units in the project area or justify its absence.

To capture the effects of forest ecological restoration treatments, project developers must sample restoration units as a function of both restoration unit size and forest composition. Monitoring plots within restoration units must be permanent for the project-crediting period. At a minimum the following data parameters must be monitored annually:

- Number and location of restoration units – in the form of geodetic shapefiles
- Number, location and area of sample plots- GPS coordinates and acres[2]
- Tree species-list
- Tree biomass-tons, by tree species
- Harvested wood products volume, if selected-tons
- Dead wood pool, tons

Annual monitoring may be completed with models or site visits. Project are does not change after initial validation. However, during project planning and prior to registration, project developers may opt to exclude portions of a restoration unit as outlined in the NEPA document from the project area during project development when:

- Management is dictated by alternate regulations (e.g. wilderness study areas, endangered species protected areas and so forth)
- Restoration units abut human infrastructure that alters management prescriptions or needs
- Specific challenges as agreed upon by public land management agencies and project developers, justified within the project design documents.

Portions would be excluded for the full project term and approved by ACR prior to project initiation.

D.2 MONITORING PROJECT IMPLEMENTATION

For all carbon pools, a detailed description of the inventory sampling methodology used to quantify that carbon pool, with references clearly documented must be supplied along with:

- Documentation of all analytic methods including volume models and biomass equations used

- A documented quality assurance / quality control (QA/QC) plan including procedures for internal review to ensure that standard operating procedures are being followed
- Description of data management systems and processes, including the collection, storage, and analysis of inventory data
- A change log documenting any changes in the inventory methods, volume models, or biomass equations used to calculate carbon stocks

D.3 MONITORING OF CARBON STOCKS IN SELECTED POOLS

D.3.1 TREE CARBON STOCK CALCULATION

The initial mean carbon stock in above and belowground biomass per acre, per restoration unit are modeled with ClimateFVS based on field measurements in sample plots. A sampling plan must be developed that describes the inventory process including sample size, determination of plot layout and locations, and data collected. Plot data used for biomass calculations may not be older than 10 years. Plots must be permanent for the project term. Carbon stocks must be modeled in-between site visits using a previously listed (section 3.1.3) model and updated with inventory plot data as available.

D.3.1.1 CARBON STOCK CALCULATION STEPS

Biomass for each tree is calculated from its merchantable volume using a component ratio method [44]. The The following steps are used to calculate tree biomass:

Step 1: Determine the biomass of the merchantable component of each tree based on appropriate volume equations published by USDA Forest Service (if locally derived equations are not available use regional or national equations as appropriate) and green volume inside bark, oven-dry tree specific gravity for each species.

Step 2: Determine aboveground biomass by choosing a combination of the following components: stump, bark, tops and branches, and/or foliage, in addition to below-ground biomass, by applying component ratios from Jenkins *et al* (2003) Table 6[19], where biomass of each component is calculated as its component ratio * merchantable stem biomass from Step 1 * (1 / stem wood component ratio). If stump, top, and branch components are included, please use the quantification methodology found in

[44] California Environmental Protection Agency Air Resources Board, "Compliance Offset Protocol: U.S. Forest Projects" (2014).

Woodall et al. 2011[20]. Note that the same components must be calculated for *ex ante* and *ex post* baseline and project estimates.

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.

Note: The FVS Fire and Fuels Extension volume-based default estimates[21] of Live Carbon are compliant with the

above, but do not include bark and stump components.

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D.3.1.2 DEAD WOOD CALCULATION

Dead wood included in the methodology comprises two components: standing dead wood 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.

D.3.1.2.1 STANDING DEAD WOOD

Step 1: Standing dead trees greater than 15 feet in height shall be measured using the same criteria and monitoring frequency used for measuring live trees. The decomposed portion that corresponds to the original above□ground biomass is discounted. Belowground standing dead wood is conservatively excluded.

Step 2: The decomposition class of the standing dead tree and the diameter at breast height shall be recorded and the standing dead wood is categorized under the following four decomposition classes:

1. Tree with branches and twigs that resembles a live tree (except for leaves)
2. Tree with no twigs but with persistent small and large branches

3. Tree with large branches only
4. Bole only, no branches

Step 3: Biomass must be estimated using the component ratio method (Appendix J: ARB US Forests Compliance Offset Protocol, n.d.) used for live trees in the decomposition class. When the bole is in decomposition classes 2, 3 or 4, the biomass estimate must be limited to the main stem of the tree. If the top of the standing dead tree is missing, then top and branch biomass may be assumed to be zero. Identifiable tops on the ground meeting category 1 criteria may be directly measured. For trees broken below minimum merchantability specifications used in the tree biomass equation, existing standing dead tree height shall be used to determine tree bole biomass.

Step 4: The biomass of dead wood is determined by using the following dead wood density classes deductions: Class 1 – same as live tree biomass; Class 2 – 95% of live tree biomass; Class 3 – 90% of live tree biomass; Class 4 – 80% of live tree biomass.

Step 5: Complete steps 3-7 from 4.1.1 to determine strata level standing dead carbon and complete table D.1 for standing dead wood.

D.3.1.2.2 LYING DEAD WOOD

The lying dead wood pool is expected to increase following wildfire or prescribed burning [45].

Step 1: Lying dead wood must be sampled using the line intersect method (Harmon and Sexton 1996). 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.

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 Good Practice Guidance for LULUCF (2003), Section 4.3.3.5.3. 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.

Step 3: The volume of lying dead wood per unit area is calculated using the equation [46] as modified by Van Wagner [47] (1968) separately for each density class (equation D.2).

[45] Kent, Larissa L. Yocom, et al. "Interactions of fuel treatments, wildfire severity, and carbon dynamics in dry conifer forests." *Forest Ecology and Management* 349 (2015): 66-72.

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

[47] C. E. Van Wagner "The line intersect Method in forest Fuel Sampling". Forest Science (1968) 14(1):20-26.h

Equation D.2: Volume of lying dead wood

$$V_{LDW,DC} = \pi^2 \left(\sum_{n=1}^{N} D_{n,DC}^2 \right) / 8 \cdot L$$	
Where:	
$V_{LDW,DC}$	Volume (in cubic meters per hectare) of lying dead wood in density class DC per unit area;
$D_{n,DC}^2$	Diameter (in centimeters) 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 should be converted into biomass using the following relationship:

Equation D.3: Biomass of lying dead wood

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

D.3.2 TOTAL PROJECT CARBON STOCK CALCULATION

To calculate the total carbon storage per restoration unit, the inventory estimates from table D.1 for standing live and dead wood must be summed (equation D-4).

Equation D.4: Tree Carbon Stocks

$$C_{stock_i} = (C_{LW} + C_{DW})$$	
Where:	
C_{LW}	represents the sum of carbon stock in living trees from table D.1 for strata *i*, year *t*; tons C
C_{DW}	represents the sum of carbon stocks in dead wood pools (a sum of lying dead wood and standing dead wood) from table D.1 for strata *i,* year t; tons C

D.3.3 ACCOUNTING FOR UNCERTAINTY IN ESTIMATES OF TREE CARBON STOCKS

This methodology utilizes confidence deduction methods laid out in the ACR Forest Project Standard. Where statistical confidence is low, there is a higher risk of overestimating a project's actual carbon stocks and therefore a higher risk of over-quantifying GHG reductions and GHG removal enhancements. To help ensure that estimates are conservative, a confidence deduction must be applied each year to the inventory of actual onsite carbon stocks. A confidence deduction is not applied to the forest carbon inventory when it is used to model baseline carbon stocks.

To determine the appropriate confidence deduction, perform the following:

Step 1: Compute the standard error of the inventory estimate (based on the carbon in all carbon pools included in the forest carbon inventory).

Step 2: Multiply the standard error by 1.645.

Step 3: Divide the result in (2) by the total inventory estimate and multiply by 100. This establishes the sampling error (expressed as a percentage of the mean inventory estimate from field sampling) for a 90 percent confidence interval.

Step 4: Consult Table D.2 to identify the percent confidence deduction that must be applied to the inventory estimate for the purpose of calculating GHG reductions and removals.

Table D.2: Forest carbon inventory confidence deductions based on level of confidence in the estimate derived from field sampling.

Sampling error (% of inventory estimate)	Confidence deduction
0 to 5%	0%
5.1-19.9%	Sampling error - 5% (rounded to the nearest 1/10th percentage)

≥20%	100%

The confidence deduction must be updated each time sampling occurs (minimum every 5 years), but must remain unchanged between on-site verifications. If increased sampling over time results in a lower confidence deduction at the time of verification, the lower deduction must be applied to inventory estimates in the most recent reporting period subject to verification at that time. Emission Reduction Tons (ERTs) may be issued in the most recent reporting period for any verified increase in quantified GHG reductions and GHG removal enhancements associated with the new (lower) confidence deduction. Conversely, if a loss of qualified sampling plots results in a higher confidence deduction, this higher deduction is applied to the inventory estimates in the most recent reporting period subject to verification at that time. Any resulting decrease in quantified GHG reductions and GHG removal enhancements from prior years as a result of the increased confidence deduction will be treated as an intentional reversal.

D.3.4 ESTIMATING CARBON IN WOOD PRODUCTS POOL (OPTIONAL)

Wood products may constitute a reservoir for storing carbon over the long term. Projects that increase wood product production can receive credit for the resulting incremental carbon storage. For projects that choose not to elect the harvested wood option, all carbon removed during fuels treatments are counted as a source.

Accounting for wood product carbon must be applied only to actual volumes of wood harvested from within the project area. Trees harvested outside of the project area are not part of the forest project and must be excluded from any calculations. GHG removal enhancements must be effectively "permanent," meaning that sequestered carbon associated with GHG reductions and removals must remain stored for at least 40 years. Wood product carbon is estimated by calculating the average amount of carbon that is likely to remain stored in wood products, both in products and landfills, over a 40-year period.

The following information is required to determine the amount of carbon in the harvested wood pool:

1. Volume (cubic feet) or green weight (lbs.), and by species harvested for each year
2. Percent of trees harvested that are delivered to mills
3. Mill location
4. Percent of harvested wood which will end up in the following categories:
    - Softwood lumber
    - Hardwood lumber
    - Softwood plywood
    - Oriented strandboard
    - Non-structural panels
    - Miscellaneous products
    - Paper

For methods to calculate carbon stored in the harvest wood pool C_{WP} reference appendix C of the ARB Forest Carbon Protocol [48] .

D.4 MONITORING OF EMISSION SOURCES

D.4.1 PRESCRIBED AND NATURAL BURN EMISSIONS

Project developers must gather annual shapefiles on prescribed burns and naturally occurring wildfire including severity class , then scale the burn emissions based on the total area within each burn class (equation D-5). Using the same parameters laid out in C3.1.2 and C3.1.3, project developers must model mean prescribed burn emission constants in three burn classes.

Data for this component may be generated at the USDA forest level or extracted from the FIRESEV dataset. FIRESEV (FIRE SEVerity Mapping Tools) is a comprehensive set of tools and protocols to deliver, create, and evaluate fire severity maps for all phases of fire management. It can be used to create real-time fire severity maps on its own or along with current satellite imagery products to enhance data analysis of fire effects.

Equation D.5: Prescribed and natural burn emissions

B1 Class 1: Units which are not slated for fuels treatments B2 Class 2: Units which have received fuels treatments B3 Class 3: Units which are slated for fuels treatments but have not yet received them (e.g. overstocked stands) Where burn classes have the units tCO2e acre-1 prescribed fire-1 and are output by previously listed fire models (C3.1.2 and C3.1.3).	
$B_t = (B_1 \times A_{B1_t}) + (B_2 \times A_{B2_t}) + (B_3 \times A_{B3_t})$	
Where:	
B_t	is the sum of all prescribe burn emissions in year t; tons CO_2e
B_1	is the project developer derived constant for burn class 1; tons CO_2e acre^{-1} prescribed fire^{-1}
A_{B1_t}	is the area burned in class 1, year t; acres
B_2	is the project developer derived constant for burn class 2; tons CO_2e acre^{-1} prescribed fire^{-1}
A_{B2_t}	is the area burned in class 2, year t; acres
B_3	is the project developer derived constant for burn class 3; tons CO2e acre-1 prescribed fire-1

[48] California Environmental Protection Agency Air Resources Board, "Compliance Offset Protocol: U.S. Forest Projects" (2014).

A_{B3_t}	is the area burned in class 3, year t; acres

Projects which have completed mechanical treatments and have issued ERTs must report annual changes in carbon stocks and emissions due to fire to the American Carbon Registry even in years which they are not completing a full inventory or generating ERTs (see Reversals section B.5.1).

D.4.2 FUELS TREATMENT EMISSIONS

Project developers must estimate total fossil fuel emissions which result from fuels treatment activities in years where treatments occur, delineated as E_{OPS}. Estimates may be based on current, regionally specific scientific literature or tracked and recorded in compliance with an internationally recognized greenhouse gas inventory methodology[49,50,51,52,53].

D.5 ESTIMATION OF PROJECT EMISSION REDUCTIONS OR ENHANCED REMOVALS

D.5.1 TREATMENT SHADOW EFFECT EMISSIONS REDUCTION(Optional)

Treatment shadow effects are the changes in fire behavior or emissions stemming from adjacent treatments (i.e. fuels and prescribed burns) and are quantified in the framework as the expected change in fire size and/or severity due to fuels treatments. Indirect emissions benefit from reduced severe wildfire severity on adjacent lands is calculated by modeling treated and un-treated stands, capturing changes in wildfire severity and size, and scaling that to emissions savings. Stands which reach or return to a WHP of high or very high are excluded from this benefit (section C2). The analysis is conducted for the complete time period adjusted by the risk of fire. As this component may add significant uncertainty to ERT generation it is an optional component of this methodology.

Equation D.6: Treatment shadow effect emissions reduction

$$W_{Shadow} = (W_{DE} \times W_{RFS})$$	
Where:	

[49] M. North, M. Hurteau, J. Innes, "Fire suppression and fuels-treament on mixed-conifer carbon and emissions" *Ecol. Appl.* **19**, 1385–1396 (2009).
[50] A. J. Finkral, A. M. Evans, "The effects of a thinning treatment on carbon stocks in a northern Arizona ponderosa pine forest" *For. Ecol. Manage.* **255**, 2743–2750 (2008).
[51] S. L. Stephens, J. J. Moghaddas, B. R. Hartsough, E. E. Y. Moghaddas, N. E. Clinton, "Fuel treatment effects on stand-level carbon pools, treatment-related emissions, and fire risk in a Sierra Nevada mixed-conifer forest" *Can. J. For. Res.* **39**, 1538–1547 (2009).
[52] The Climate Registry, "General Reporting Protocol" (2013).
[53] World Resources Institute, "Greenhouse Gas Protocol" (2006).

W_{Shadow}	is the projected potential change in direct wildfire emissions from wildfire combustion at time *t* for the untreated landscape which is influenced by the treated landscape for year *t*; tons CO_2e
W_{DE}	is the projected potential direct emission from wildfire combustion summed for year *t*; tons CO_2e
W_{RFS}	is the reduction in fire size and/or severity expected from project treatment implementation calculated from fire models (see C3.2 above)

D.5.2 CALCULATION OF TOTAL PROJECT CARBON EMISSIONS REDUCTIONS

This section describes the steps required to calculate C_{P_t} (Net carbon stock at time *t* under the project scenario; tons CO_2e), which is defined as:

Equation D.7: Total project carbon emissions reductions

$$C_{P_t} = \sum_{i=1}^{n} C_{P_i} + C_{WP_t} + W_{Shadow} - E_{OPS} - B_t$$

Where:	
C_{P_t}	is carbon stocks in live and dead wood within the project scenario for all trees and all strata in year *t*; tons CO_2e
C_{P_i}	is carbon stocks in live and dead wood within restoration unit i, year t; tons CO2e
C_{WP}	is carbon stocks in the harvested wood products pool for year t; tons CO2e
W_{Shadow}	is the projected potential change in Direct Wildfire Emissions from wildfire combustion at time t for the untreated landscape which is influenced by an adjacent treated landscape; tons CO2e
E_{OPS}	is the direct GHG emissions from fossil fuel combustion associated with silviculture/restoration/small diameter wood extraction and fuels treatments for year t; tons CO2e
B_t	is the sum of all prescribed and natural burn emissions in year t; tons CO2e

D.6 MONITORING LEAKAGE

As per the applicability conditions, leakage is assumed to be *de minimis* provided that project activities exceed baseline levels of commercial and non-commercial removal of biomass. Leakage from activity shifting must be re-evaluated at each crediting period. If leakage is discovered, project developers must estimate the associated leakage amount and deduct ERTs to fully compensate for emissions resulting from activity shifting leakage.

D.7 ESTIMATION OF EMISSIONS DUE TO LEAKAGE

Project activity by definition will increase small diameter wood extraction and/or prescribed burning over the baseline. Leakage emissions are therefore expected to be *de minimis*.

D.8 ESTIMATION OF WITH PROJECT UNCERTAINTY

It is important that the process of project planning consider uncertainty. Procedures including stratification and the allocation of sufficient measurement plots can help ensure low uncertainty. It is good practice to consider uncertainty at an early stage to identify the data sources with the highest risk to allow the opportunity to conduct further work to diminish uncertainty.

Uncertainties arising from the measurement and monitoring of carbon pools and the changes in carbon pools must always be quantified. Indisputably conservative estimates can also be used instead of uncertainties, provided that they are based on verifiable literature sources. In this case the uncertainty is assumed to be zero. However, this module provides a procedure to combine uncertainty information and conservative estimates resulting in an overall project scenario uncertainty.

D.8.1 PROJECT UNCERTAINTY CALCULATION

The uncertainty in the project scenario should be defined as the square root of the summed errors in each of the measurement pools (equation D-6) using 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.

Equation D.8: Project Uncertainty

$$Uncertainty_{P,SS,i} = \frac{\sqrt{(U_{P,SS1,i} \times E_{BSL,SSi,i})^2 + (U_{P,SS2,i} \times E_{P,SS2,i})^2 + \cdots + (U_{P,SSn,i} \times E_{P,SSn,i})^2}}{E_{P,SSi,i} + E_{P,SS2,i} + E_{P,SSn,i}}$$

Where:	
$Uncertainty_{P,SS,i}$	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the project case in restoration unit i; %
$U_{P,SS,i}$	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in restoration unit i (1,2…n represent different carbon pools and/or GHG sources); %
$E_{P,SS,i}$	Carbon stock or GHG sources (e.g. trees, dead wood, emission from prescribed burning, harvested wood products) in restoration unit i (1,2…n represent different carbon pools and/or GHG sources) in the project case; t CO2-e
I	1, 2, 3 …n restoration units

E. EX-ANTE ESTIMATION

E.1 EX-ANTE ESTIMATION METHODS

The project developer must make an ex ante calculation of all net anthropogenic GHG removals and emissions for all included sinks and sources for the entire project period. Project participants shall provide estimates of the values of those parameters that are not available before the start of monitoring activities. Project participants must retain a conservative approach in making these estimates.

Uncertainties arising from, for example, biomass expansion factors or wood density, could result in unreliable estimates of both baseline net GHG removals by sinks and the actual net GHG removals by sinks especially when global default values are used. Project developers shall identify key parameters that would significantly influence the accuracy of estimates. Local values that are specific to the project circumstances must then be obtained for these key parameters, whenever possible. These values must be based on:

- Data from well-referenced peer-reviewed literature or other well-established published sources; or
- 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 briefly noted in the GHG plan. For any data provided by experts, the GHG Plan shall also record the expert's name, affiliation, and principal qualification as an expert plus inclusion of a 1-page summary CV for each expert consulted, included in an annex.

When choosing key parameters based on information that is not specific to the project circumstances, such as in use of default data, project developers must select values that will lead to an accurate estimation of net GHG removals by sinks, taking into account uncertainties. If uncertainty is significant, project participants must choose data such that it tends to under-estimate, rather than over-estimate, net GHG removals by sinks.

F. QUALITY ASSURANCE, QUALITY CONTROL AND UNCERTAINTY

F.1 METHODS FOR QUALITY ASSURANCE

Standard operating procedures (SOPs) and quality control / quality assurance (QA/QC) procedures for forest inventory including field data collection and data management shall be documented in the sampling plan. Use or adaptation of SOPs already applied in national forest monitoring, or available from published handbooks, or from the IPCC Good Practice Guidance LULUCF 2003, is recommended.

F.2 METHODS FOR QUALITY CONTROL

Project developers shall consider all relevant information that may affect the accounting and quantification of GHG 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. 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.

F.3 CALCULATION OF UNCERTAINTY

Total project uncertainty is composed of both project and baseline level uncertainties and is subtracted from the overall net project GHG reduction to remain conservative.

Equation F.1: Total Uncertainty

$$UNC = \sqrt{UNC_{BSL}^{\ 2} + UNC_{WP}^{\ 2}}$$

Where:	
UNC	Total project Uncertainty, in %
UNC_{BSL}	Baseline uncertainty, in % (Section C6)
UNC_{WP}	With-project uncertainty, in % (Section D8)
UNC will be set to zero if the project achieves ACR's precision requirement of within 10% of the mean with 90% confidence.	

G. CALCULATION OF EMISSION REDUCTION TONS

G.1 CALCULATION OF ERTs

Emission reduction tons are calculated as the difference between a fit of the baseline and a fit of the project scenario carbon storage (less any losses due to leakage and removals for buffer pool). These fits must be based on a minimum of 5 years of data, and must include all available data since the project start. Fits chosen must maximize R^2 values. This method is used for estimating ERTs because annual variability in carbon stocks is expected due to fuel reduction treatments, prescribed burns, and unplanned natural fires (Fig 1) that occur as part of the project.

A reversal of carbon stocks would only occur if any planned or unplanned event decreases carbon stocks in the project area significantly enough to reduce the fit of the project scenario to be >3% below ERTs previously issued (Fig 2). In the case of a reversal, any planned or unplanned loss of carbon stocks in the project area must be documented and accounted for by recalculating the project scenario linearized carbon storage.

Project developers may only claim emission reduction tons when linearized project scenario carbon stocks exceed previously issued carbon stock levels.

The total emission reduction tons represent the difference between baseline and project scenario carbon storage, accounting for losses due to leakage (assumed to be *de minimis* in this methodology), along with conservative removals to capture uncertainty. Within this project it is expected that carbon stocks will fluctuate with fuels treatments and prescribed burns. As such project developers may only claim additional carbon resulting from the fitted trend in storage between the baseline and project scenarios at any given point in time (see figure 7). Total net GHG emission reductions are calculated with equation G.1.

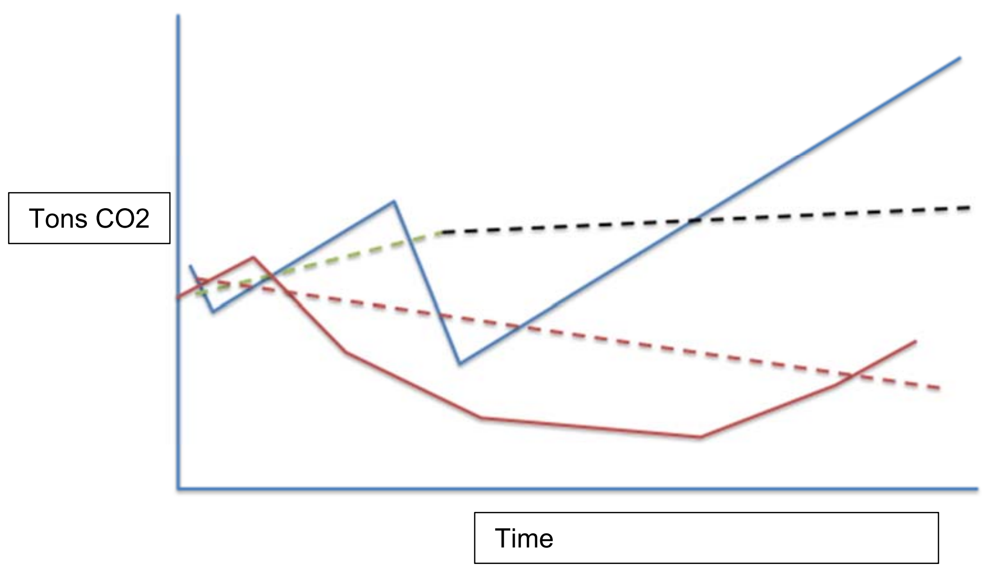

Figure 7: Example of linearized versus actual or modelled carbon stocks.

Equation G.1: Calculation of Carbon Emission Reductions

$$C_{ACR,t} = (\Delta C_P - \Delta C_{BSL} - \Delta C_{LK}) * (1 - UNC)$$

Where:	
$C_{ACR,t}$	Total net greenhouse gas emission reductions at time t (t CO2e)
ΔC_P	Sum of the carbon stock changes and greenhouse gas emissions under the project scenario up to time t, in t CO2e (Section D4)
ΔC_{BSL}	Sum of the carbon stock changes and greenhouse gas emissions under the baseline scenario up to time t, in t CO2e (Section C3/C4)
ΔC_{LK}	Sum of the carbon stock changes and greenhouse gas emissions due to leakage up to time t, in t CO2e (Section D6)
UNC	Total Project Uncertainty, in % (Section F3). UNC will be set to zero if the project meets ACR's precision requirement of within 10% of the mean with 90% confidence. If the project does not meet this precision target, UNC should be the half-width of the confidence interval of calculated net GHG emission reductions.

The quantity of emissions reductions that are claimed at year t is a function of the change in carbon since the last crediting period, minus a non-permanence buffer deduction to account for unexpected changes in carbon reversal, based on risk. Therefore, ERT's are calculated with equation G.2.

Equation G.2: Calculation of emission reduction tons

$$ERT_t = \left(C_{ACR,t_2} - C_{ACR,t_1}\right) * \left(1 - BUF\right)$$

Where:	
$ERT_{,t}$	Number of Emission Reduction Tons at time $t = t_2 - t_1$
$C_{ACR,t2}$	Cumulative total net GHG emissions reductions up to time t_2
$C_{ACR,t1}$	Cumulative total net GHG emissions reductions up to time t_1
BUF	The non-permanence buffer deduction as calculated by the ACR Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination (BUF will be set to zero if an ACR approved insurance product is used)

H. APPENDIX – EXAMPLE OF INTEGRATING BEST PRACTICE FVS PARAMETERS FOR THE SOUTHWESTERN US

When multiple publications or datasets exist within the national forest or project area, a mean across sources should be demonstrated. See examples below:

Example 1: Regeneration

Citation 1: Delayed regeneration: 20 years

Citation 2: Delayed regeneration 10 years

Delayed regeneration component entered into ClimateFVS: 15 years with attached calculations and citations.

When taking the mean across alternate ecosystems the total probability must sum to 1, rounding down on alternate ecosystem succession to remain conservative.

Example 2: Alternate ecosystem regeneration

Citation 1:	Ponderosa	60%	Citation 2:	40%	Mean:	50%
	Pinyon Juniper	20%		10%		15%
	Grassland	20%		50%		35%

Alternate ecosystem regeneration input into ClimateFVS would be that of the mean across citations with citations and calculations attached.

A large repository of relevant material can be found at the Ecological Restoration Institute, Fulé Lab and Hurteau lab among other. Whenever possible project developers shall choose conservative estimates and justify their selection.

I. APPENDIX – DATA AND PARAMETERS

Table H.1: Parameter definitions

Parameter	Unit	Description	Source	Used in Eq.
T	time	time		
$C_{BSL,PROJ_t}$	tons CO_2e	represents the sum of all carbon stocks in the baseline scenario projection for year *t including forested, burnt and alternate ecosystems*		C-1
$C_{BSL,LW_{i_t}}$	tons CO_2e	represents carbon stocks in baseline live trees for restoration unit or sub-unit i, year t	Measurements and model	C-1

$C_{BSL,DW_{i_t}}$	tons CO_2e	represents carbon stocks in baseline dead wood pools for restoration unit or sub-unit i, year t	Measurements and model	C-1
W_{DE}	tons CO_2e	is the projected potential Direct Emission from wildfire combustion for year *t*, restoration unit or sub-unit *i*;	Fire model	C-1
$W_{WeibullProb}$	probability	is the cumulative probability of wildfire for year *t* within restoration unit or sub-unit i	36	C-1
$AW_{fireshed\ i}$	%	is the area weight of restoration unit or sub-unit i, relative to total project area;	Project records	C-1
B		scale parameter	36	C-2
c		the shape parameter	36	C-2
$Uncertainty_{BSL,SS,i}$	%	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the baseline case in stratum i		C-3
$U_{BSL,SS,i}$	%	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline case in stratum *i* (1,2…n represent different carbon pools and/or GHG sources);		C-3
$E_{BSL,SS,i}$	t CO2-e	Carbon stock or GHG sources (e.g. trees, dead wood, wildfire emissions) in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) in the baseline case;		C-3
i	Area	1, 2, 3 …n restoration unit or sub-units, fireshed		C-3
C_{stock_i}	tons c	$(C_{LW} + C_{DW})$	Measurements and model	D-2
C_{LW}	tons c	represents the sum of carbon stock in living trees from table D.1 for strata *i*, year *t*;	Measurements and model	D-2
C_{DW}	tons c	represents the sum of carbon stocks in dead wood pools from table D.1 for strata *i*, year t;	Measurements and model	D-2
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t	Fire model	D-3
B_1	tons CO_2e $acre^{-1}$	Units which are not slated for fuels treatments; is the project	Fire model	D-3

	prescribed fire^{-1}	developer derived constant for burn class 1		
B_2 Class 2	tons CO_2e acre^{-1} prescribed fire^{-1}	Units which have received fuels treatments is the project developer derived constant for burn class 2;	Fire model	D-3
A_{B1_t}	acres	is the area burned in class 1, year t	Project records, MTBS	D-3
A_{B2_t}	acres	is the area burned in class 2, year t	Project records, MTBS	D-3
B_3 Class 3	tons CO_2e acre^{-1} prescribed fire^{-1}	Units which are slated for fuels treatments but have not yet received them (e.g. overstocked stands) is the project developer derived constant for burn class 3;	Fire model	D-3
A_{B3_t}	acres	is the area burned in class 3, year t	Project records, MTBS	D-3
W_{Shadow}	tons CO_2e	is the projected potential change in direct wildfire emissions from wildfire combustion at time *t* for the untreated landscape which is influenced by the treated landscape for year *t*;	Fire model	D-4
W_{DE}	tons CO_2e	is the projected potential direct emission from wildfire combustion summed for year *t*;	Fire model	D-4
W_{RFS}	Biomass burned	is the reduction in fire size and/or severity expected from project treatment implementation calculated from fire models	Fire model	D-4
C_{P_t}	tons CO_2e	is carbon stocks in live and dead wood within the project scenario for all trees and all strata in year *t*	Measurements and model	D-5
C_{P_i}	tons CO_2e	is carbon stocks in live and dead wood within restoration unit i, year t;	Measurements and model	D-5
C_{WP}	tons CO_2e	is carbon stocks in the tons CO_2e harvested wood products pool for year *t*;	Measurements and model	D-5
E_{OPS}	tons CO_2e	is the direct GHG emissions associated with small diameter wood extraction and fuels treatments for year *t*;	Measurements and model	D-5
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t;	Fire model	D-5
$Uncertainty_{P,SS,i}$	%	Percentage uncertainty in the combined carbon stocks and		D-6

		greenhouse gas sources in the project case in restoration unit *i*;		
$U_{P,SS,i}$	%	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in restoration unit i (1,2…n represent different carbon pools and/or GHG sources);		D-6
$E_{P,SS,i}$	t CO2-e	Carbon stock or GHG sources (e.g. trees, dead wood, emission from prescribed burning, harvested wood products) in restoration unit *i* (1,2…n represent different carbon pools and/or GHG sources) in the project case;		D-6
UNC	%	Total project Uncertainty. *UNC* will be set to zero if the project achieves ACR's precision requirement of within 10% of the mean with 90% confidence.		F-1
UNC_{BSL}	%	Baseline uncertainty		F-1
UNC_{WP}	%	With-project uncertainty		F-1
$C_{ACR,t}$	t CO_2e)	Total net greenhouse gas emission reductions at time *t* (t CO_2e)		G-1
ΔC_P	t CO_2e	Sum of the carbon stock changes and greenhouse gas emissions under the project scenario up to time *t*,		G-1
ΔC_{LK}	t CO_2e	Sum of the carbon stock changes and greenhouse gas emissions due to leakage up to time *t*, in t CO_2e		G-1
UNC	%	Total Project Uncertainty, in %. (*UNC* will be set to zero if the project meets ACR's precision requirement of within 10% of the mean with 90% confidence. If the project does not meet this precision target, *UNC* should be the half-width of the confidence interval of calculated net GHG emission reductions.)		G-1
$ERT_{,t}$	t CO_2e	Number of Emission Reduction Tons at time $t = t_2 - t_1$		G-2

$C_{ACR,t2}$	t CO_2e	Cumulative total net GHG emissions reductions up to time t_2		G-2
$C_{ACR,t1}$	t CO_2e	Cumulative total net GHG emissions reductions up to time t_1		G-2
BUF	fraction	The non-permanence buffer deduction as calculated by the ACR Tool for AFOLU Non-Permanence Risk Analysis and Buffer Determination (*BUF* will be set to zero if an ACR approved insurance product is used)		G-2

Table H.2: Parameters established at validation

Parameter	Unit	Description	Source	Used in Eq.
t	time	time		
$C_{BSL,PROJ_t}$	tons CO_2e	represents the sum of all carbon stocks in the baseline scenario projection for year *t including forested, burnt and alternate ecosystems*		C-1
$C_{BSL,LW_{i_t}}$	tons CO_2e	represents carbon stocks in baseline live trees for restoration unit or sub-unit i, year t	Measurements and model	C-1
$C_{BSL,DW_{i_t}}$	tons CO_2e	represents carbon stocks in baseline dead wood pools for restoration unit or sub-unit i, year t	Measurements and model	C-1
W_{DE}	tons CO_2e	is the projected potential Direct Emission from wildfire combustion for year *t*, restoration unit or sub-unit *i*;	Fire model	C-1
$W_{WeibullProb}$	probability	is the cumulative probability of wildfire for year *t* within restoration unit or sub-unit i	36	C-1
$AW_{fireshed\ i}$	%	is the area weight of restoration unit or sub-unit i, relative to total project area;	Project records	C-1
b		scale parameter	36	C-2
c		the shape parameter	36	C-2
$Uncertainty_{BSL,SS,i}$	%	Percentage uncertainty in the combined carbon stocks and		C-3

		greenhouse gas sources in the baseline case in stratum i		
$U_{BSL,SS,i}$	%	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the baseline case in stratum *i* (1,2…n represent different carbon pools and/or GHG sources);		C-3
$E_{BSL,SS,i}$	t CO2-e	Carbon stock or GHG sources (e.g. trees, dead wood, wildfire emissions) in stratum *i* (1,2…n represent different carbon pools and/or GHG sources) in the baseline case;		C-3
i	area	1, 2, 3 …n restoration unit or sub-units or fireshed		C-3
C_{stock_i}	tons c	$(C_{LW} + C_{DW})$	Measurements and model	D-2
C_{LW}	tons c	represents the sum of carbon stock in living trees from table D.1 for strata *i*, year *t*;	Measurements and model	D-2
C_{DW}	tons c	represents the sum of carbon stocks in dead wood pools from table D.1 for strata *i,* year t;	Measurements and model	D-2
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t		D-3
B_1	tons CO_2e acre^{-1} prescribed fire^{-1}	Units which are not slated for fuels treatments; is the project developer derived constant for burn class 1	Fire model	D-3
B_2 Class 2	tons CO_2e acre^{-1} prescribed fire^{-1}	Units which have received fuels treatments is the project developer derived constant for burn class 2*;*	Fire model	D-3
A_{B1_t}	acres	is the area burned in class 1, year t	Project records, MTBS	D-3
A_{B2_t}	acres	is the area burned in class 2, year t	Project records, MTBS	D-3
B_3 Class 3	tons CO_2e acre^{-1} prescribed fire^{-1}	Units which are slated for fuels treatments but have not yet received them (e.g. overstocked stands) is the project developer derived constant for burn class 3;	Fire model	D-3
A_{B3_t}	acres	is the area burned in class 3, year t	Project records, MTBS	D-3

W_{Shadow}	tons CO_2e	is the projected potential change in direct wildfire emissions from wildfire combustion at time *t* for the untreated landscape which is influenced by the treated landscape for year *t*;	Fire model	D-4
W_{DE}	tons CO_2e	is the projected potential direct emission from wildfire combustion summed for year *t*;	Fire model	D-4
W_{RFS}	Biomass burned	is the reduction in fire size and/or severity expected from project treatment implementation calculated from fire models	Fire model	D-4
C_{P_t}	tons CO_2e	is carbon stocks in live and dead wood within the project scenario for all trees and all strata in year *t*	Measurements and model	D-5
C_{P_i}	tons CO_2e	is carbon stocks in live and dead wood within restoration unit i, year t;	Measurements and model	D-5
C_{WP}	tons CO_2e	is carbon stocks in the tons CO_2e harvested wood products pool for year *t*;	Project records and model	D-5
E_{OPS}	tons CO_2e	is the direct GHG emissions associated with small diameter wood extraction and fuels treatments for year *t*;	Project records	D-5
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t;		D-5
$Uncertainty_{P,SS,i}$	%	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the project case in restoration unit *i*;		D-6
$U_{P,SS,i}$	%	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in restoration unit i (1,2…n represent different carbon pools and/or GHG sources);		D-6
$E_{P,SS,i}$	t CO2-e	Carbon stock or GHG sources (e.g. trees, dead wood, emission from prescribed burning, harvested wood products) in restoration unit *i* (1,2…n represent different carbon pools and/or GHG sources) in the project case;		D-6

UNC	%	Total project Uncertainty. *UNC* will be set to zero if the project achieves ACR's precision requirement of within 10% of the mean with 90% confidence.		F-1
UNC_{BSL}	%	Baseline uncertainty		F-1
UNC_{WP}	%	With-project uncertainty		F-1

Table H.3: Parameters monitored at each verification

C_{stock_i}	tons c	$(C_{LW} + C_{DW})$	Measurements & model	D-2
C_{LW}	tons c	represents the sum of carbon stock in living trees from table D.1 for strata *i*, year *t*;	Measurements & model	D-2
C_{DW}	tons c	represents the sum of carbon stocks in dead wood pools from table D.1 for strata *i*, year t;	Measurements & model	D-2
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t		D-3
B_1	tons CO_2e $acre^{-1}$ prescribed $fire^{-1}$	Units which are not slated for fuels treatments; is the project developer derived constant for burn class 1		D-3
B_2 Class 2	tons CO_2e $acre^{-1}$ prescribed $fire^{-1}$	Units which have received fuels treatments is the project developer derived constant for burn class 2;		D-3
A_{B1_t}	acres	is the area burned in class 1, year t	Project records, MTBS	D-3
A_{B2_t}	acres	is the area burned in class 2, year t	Project records, MTBS	D-3
B_3 Class 3	tons CO_2e $acre^{-1}$ prescribed $fire^{-1}$	Units which are slated for fuels treatments but have not yet received them (e.g. overstocked stands) is the project developer derived constant for burn class 3;		D-3
A_{B3_t}	acres	is the area burned in class 3, year t	Project records, MTBS	D-3
W_{Shadow}	tons CO_2e	is the projected potential change in direct wildfire emissions from wildfire combustion at time *t* for the untreated landscape which is influenced by the treated landscape for year *t*;	Fire model	D-4
W_{DE}	tons CO_2e	is the projected potential direct emission from wildfire combustion summed for year *t*;	Fire model	D-4

W_{RFS}	Biomass burned	is the reduction in fire size and/or severity expected from project treatment implementation calculated from fire models	Fire model	D-4
C_{P_t}	tons CO_2e	is carbon stocks in live and dead wood within the project scenario for all trees and all strata in year *t*	Measurements & model	D-5
C_{P_i}	tons CO_2e	is carbon stocks in live and dead wood within restoration unit i, year t;	Measurements & model	D-5
C_{WP}	tons CO_2e	is carbon stocks in the tons CO_2e harvested wood products pool for year *t*;	Measurements & model	D-5
E_{OPS}	tons CO_2e	is the direct GHG emissions associated with small diameter wood extraction and fuels treatments for year *t*;	Project records	D-5
B_t	tons CO_2e	is the sum of all prescribe burn emissions in year t;	Fire model	D-5
$Uncertainty_{P,SS,i}$	%	Percentage uncertainty in the combined carbon stocks and greenhouse gas sources in the project case in restoration unit *i*;		D-6
$U_{P,SS,i}$	%	Percentage uncertainty (expressed as 95% confidence interval as a percentage of the mean where appropriate) for carbon stocks and greenhouse gas sources in the project case in restoration unit i (1,2…n represent different carbon pools and/or GHG sources);		D-6
$E_{P,SS,i}$	t CO2-e	Carbon stock or GHG sources (e.g. trees, dead wood, emission from prescribed burning, harvested wood products) in restoration unit *i* (1,2…n represent different carbon pools and/or GHG sources) in the project case;		D-6
UNC	%	Total project Uncertainty. *UNC* will be set to zero if the project achieves ACR's precision requirement of within 10% of the mean with 90% confidence.		F-1
UNC_{BSL}	%	Baseline uncertainty		F-1
UNC_{WP}	%	With-project uncertainty		F-1

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