Estimating Changes in Carbon Storage in the Cragin Watershed Protection Project with the *Southwestern Forest Restoration Methodology*

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Project Summary

This case study provides a conceptual demonstration of the *Southwestern Forest Restoration: Reduced Emissions from Decreased Wildfire Severity and Forest Conversion (SFRM)* currently in scientific peer review with the American Carbon Registry. The case study applies the carbon calculation methods for comparing baseline with project scenarios proposed in the current version of the methodology to data from the Cragin Watershed Protection Project (CWPP) provided by the United States Forest Service (USFS). This data represents 37,667 acres, sampled with 220 USFS forest plots within the project area, fuel treatments planned by the USFS, and regional fire data. Four climate change scenarios were applied to account for the potential effects of climate on forests under baseline and project scenarios. **The case study modeling simulations demonstrate that restored forest in the CWPP is expected to hold 25.9 tons of carbon per acre more than an untreated forest.**

Background

There is broad agreement among the fire science community that without forest restoration treatments, large, high-severity wildfires are likely to convert southwest ponderosa pine forests to low-carbon storage savannahs, grassland and/or chaparral ecosystems. (Singleton et al., 2018; McKenzie, Gedalof, Peterson, & Mote, 2004; Stavros, Abatzoglou, McKenzie, & Larkin, 2014; Huffman, MacDonald, & Stednick, 2001; Savage & Mast, 2005). Climate change is compounding wildfire risk through heat and drought stress (Allen et al., 2010; Tarancón et al., 2014; Duffy, Schwalm, Arcus, Koch, & Schipper, in review; Williams et al., 2010; Stoddard, Sánchez Meador, Fulé, & Korb, 2015; Tarancón et al., 2014; Williams et al., 2013). In addition to high-severity fires, increasing temperatures, changes in precipitation patterns, and high densities of trees in the southwestern ponderosa pine forests threaten the viability of ponderosa pine forests in the southwest. However, fuel treatments reduce fire severity and improve forest health by reducing resource competition among remaining trees to allow for the retention of ponderosa pine forests despite climate change.

Fuel treatments in this case study were designed by the USFS and include forest thinning and prescribed fire. Fuel treatments are intended to decrease fire severity by changing forest structure through the removal of ladder fuels and decreasing overall fuel loads. Changing the structure and density of fuels alters fire behavior. In treated stands fire is expected to burn at low-severity, burn at the ground level, consume fine fuels and naturally thin small trees. In untreated stands fires burn with greater heat intensity, reaching the canopy of the forest, and killing a high proportion of all trees. In order to test this assertion, this case study models a no treatment (baseline) versus restoration treatments (project) on 37,764 acres in the CWPP.

Study Area

The CWPP area covers 64,000 acres of ponderosa pine and mixed conifer forest and is managed by the Coconino National Forest. The CWPP was planned under the authority of the Healthy Forest Restoration Act to restore forests to historical structure and fire regime and was approved for implementation in July 2018. The stated purpose of the CWPP is to "reduce the risk of uncharacteristic wildfire" (USFS, Decision Notice and Finding of No Significant Impact , 2018). Fuel reduction and forest restoration activities include prescribed fire on 63,634 acres and prescribed thinning on an overlapping 37,764 acres. This case study analyzes acres that experience mechanical thinning and/or prescribed fire treatments; only treated acres would be included in a potential IFM project. Further, it excludes all non-ponderosa pine dominant acres from carbon modeling as mixed-conifer forest types are not currently eligible for consideration under the proposed methodology.

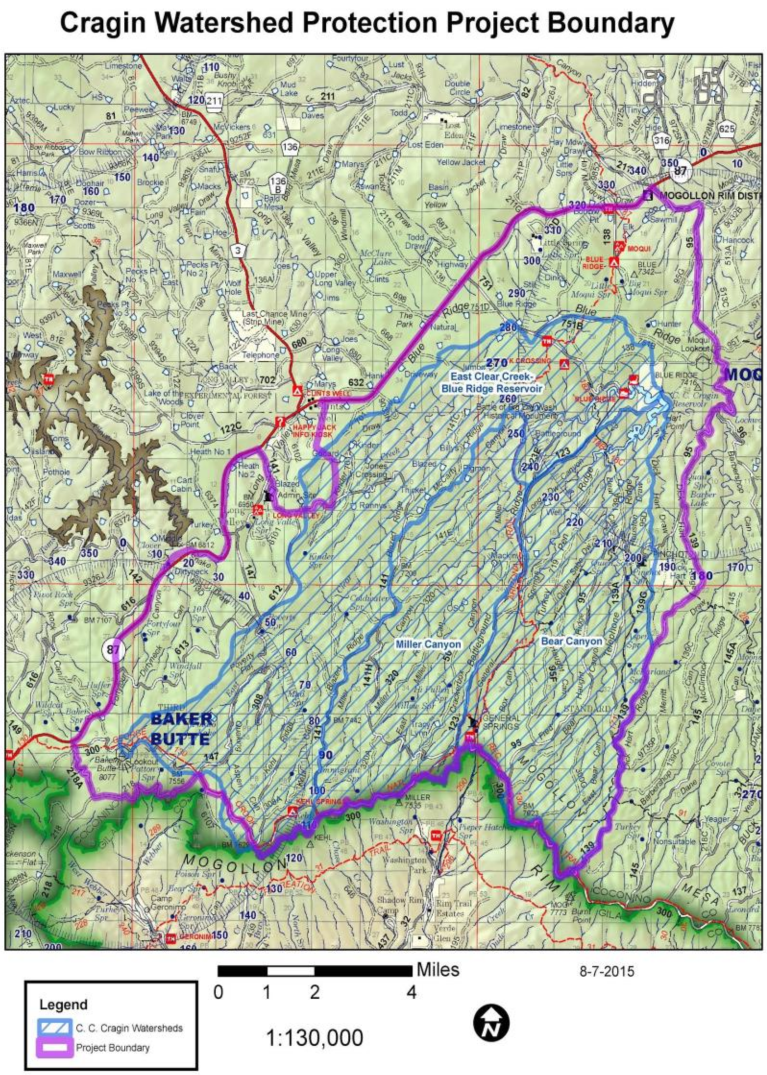


Figure 1: Case Study Area Map

Despite significant interest and planning for forest restoration by the USFS, a recent economic analysis of the CWPP (Campbell Global, 2016) suggests that restoration activities would cost between $12M-$16M due to the low economic value of harvestable timber, distance to wood markets, and high volume of non-usable biomass. These conditions suggest the CWPP would most likely meet the criteria for additionality within the methodology, as the USFS is unable to pay for the restoration treatments they have planned. A baseline scenario where little or no action can be taken to perform forest restoration as planned in the CWPP due to a lack of financial resources is likely without the development of forest carbon project. Similar planning efforts for projects like the Four Forest Restoration Initiative, a 2.4 million acre restoration effort in Arizona has largely failed to reach restoration targets due to low value of timber, costly planning, cost of treatments and inadequate funding from the USFS and other partners to pay for treatments (Esch & Vosick, 2016). This project was also examined for its ability to meet the criteria listed in Section B of the SFRM. The table is a checklist of project eligibility.

Table 1: SFRM Project Eligibility

Checklist	Project Eligibility Checklist
X	Clear land title and offsets title
X	Meet all other requirements of the ACR Standard and ACR Forest Carbon Project Standard.
X	Have legally permissible commercial timber harvesting, non-commercial harvesting, and/or prescribed fire
X	Greater than 10,000 acres of forestland.
X	Documented evidence (EA) that the project area qualifies for fuels treatment
N/A for case study	Can provide documentation of an agreement that gives explicit authorization for the public land
X	Exists within administrative boundary of Region 3 of the U.S. Forest Service.

Methods

This case study uses the same data that the USFS used for modeling forest condition and fire behavior for the planning and environmental analysis of the CWPP. The case study adheres to the above-ground carbon modeling and estimation methods laid out in the SFRM. The steps for the case study and corresponding sections of the methodology are provided in the table below:

Table 2: Sections of methodology applied for the case study

Step	Methodology Sections	Description
Baseline Modeling	Section C1, C2, C3	Run Baseline Scenario, in which no forest treatments are performed and the CWPP experience the projected fire regime of ponderosa pine forests in the Southwest.
Project Modeling	Section D3.2, D4,D5.2	Run a Project Scenario in which mechanical and prescribed fire treatments are applied to the CWPP.
ERT Calculation	Section G	Calculate Potential Emission Reduction Tons (ERT) by comparing Project Scenario with Baseline Scenario

Data

All case study data were collected and compiled according to USFS protocols for Forest Inventory and Analysis (FIA). The USFS provided data from 178 plots sampled within the CWPP for the purpose of a NEPA analysis to assess forest treatment. Forest Service resource experts provided this data to the authors, along with extensive communication and consulting regarding treatment timelines and plans. The NEPA decision document provide detailed description of the treatments planned for the CWPP.

Table 3: Data description and sources

Data Type	**Source**	**Description**
Tree lists for 178 stands within the CWPP	USFS	Forest structure used for growth and yield modeling
Latitude, longitude and elevation of all stands for climate viability scores	USFS	Calibrates model for climate scenarios for use in climate FVS
.kcp files with proposed treatments, including nine specific treatment types.	USFS	.kcp files with treatment keywords
Proposed timeline of thinning treatments across the landscape	USFS	Based on communication and .kcp files form USFS treatments were implemented over the first 5 years of the project with no re-entry
.kcp files for prescribed burns	USFS	Temp 75, RH 15, winds 10-15. 1hr 5%, 10hr 7%, 100hr 9%, 1000 hr 12%. The LH and LW 60% and 90% respectively.
Proposed implementation of prescribed burns across the landscape including return interval and annual acreage	USFS	USFS communicated that 20 year interval was reasonable for prescribed fire across all acres.
.kcp files for naturally occurring wildfire based on the Clover Fire (2016), including fuel moisture, wind speed and temperature	USFS	Very dry moisture scenario built as 1hr 2%, 10hr 3%, 100hr 5%, LH at 30% and LW at 60%. 26 mph wind speeds and 89 degrees F.
Fire Regime	USFS, LandFire	Frequency: 0 – 35 years, Severity: low/mixed. Generally low-severity fires replacing less than 25% of the dominant overstory vegetation; can include mixed-severity fires that replace up to 75% of the overstory
Mean fire return interval for Weibull distribution	LandFire	Average number of years between fires in representative stands
Propagation of wildfire across the landscape based on Weibull distribution	LandFire	Cumulative probability density function to propagate annual percentage of area that experiences wildfire
FVS parameters for regeneration and seedling survival	USFS	Generated from Coconino National Forest observations
Species viability and mortality due to climatic stress by Regional Climate Projections	Climate FVS,	Likely mortality and viability of regeneration given climate change scenario

Modeling
All stands and tree lists provided by the USFS were brought into ClimateFVS along with relevant treatments via .kcp files. All mechanical treatment simulations were implemented within the first five years of the simulation and prescribed burns were implemented on a 20 year return interval, per USFS communication.

Gridded mean fire return intervals were extracted from LandFire for each sampling plot, and were used as inputs to a Weibull distribution of fire probability for calculated fire return interval from Southwestern Forest Restoration: a protection from permanent forest loss due to high-severity wildfire and drought, with a shape parameter of 2 to indicate increased flammability of materials with age, such as dead and dry grasses common within the project area.

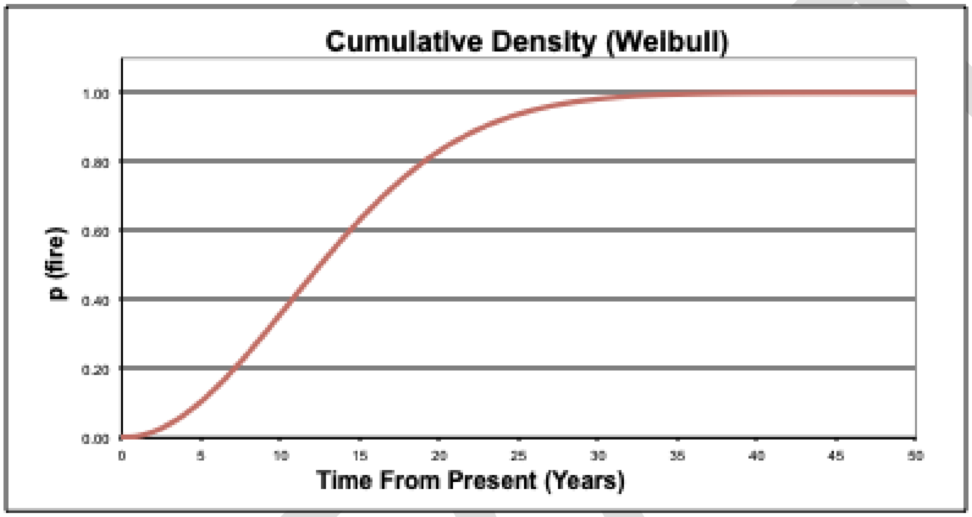


Figure 2: Probability of fire over time

Decadal estimates of wildfire occurrence were calculated from the Weibull distribution via the cumulative probability of fire at each time step, having subtracted the previous time steps cumulative probability (Table 2). This wildfire parameter was then applied as a percentage of the stand that burned within each five year time step.

Table 4: Fire probabilities at five year intervals derived from Weibull distribution

Year	Fire Probability Density Function	Cumulative Density Function	% area that burns at 5 year time steps	% burn for wildfire at midpoint and conclusion of project
5	0.03977	0.10516	0.10516	
10	0.05699	0.35882	0.25366	
15	0.04905	0.63212	0.2733	
20	0.03005	0.83099	0.19887	0.83099
40	0.00029	0.99918		0.99918

Confidence intervals for project and baseline were calculated within R statistical sofrware across all climate change scenarios, to capture all potential future outcomes. The means were calculate on five year interval. Finally, we estimated the above-ground carbon storage in project and baseline scenarios every five years.

Results

The results of this case study analysis show a clear above-ground carbon storage benefit resulting from the forest restoration treatments analyzed and selected for by the USFS for the CWPP. In Figure 3 the comparison of the project (blue line) and baseline (red line) scenarios demonstrates the difference of carbon storage in between restoration and no restoration scenarios. While initially the baseline scenario shows greater carbon storage those gains are lost to fire and climate-induce mortality, eventually leading to greater carbon storage in restored forests. The stable carbon storage in the project scenario reflects the ability of a restored forest to withstand fires due to reduced fuel loads.

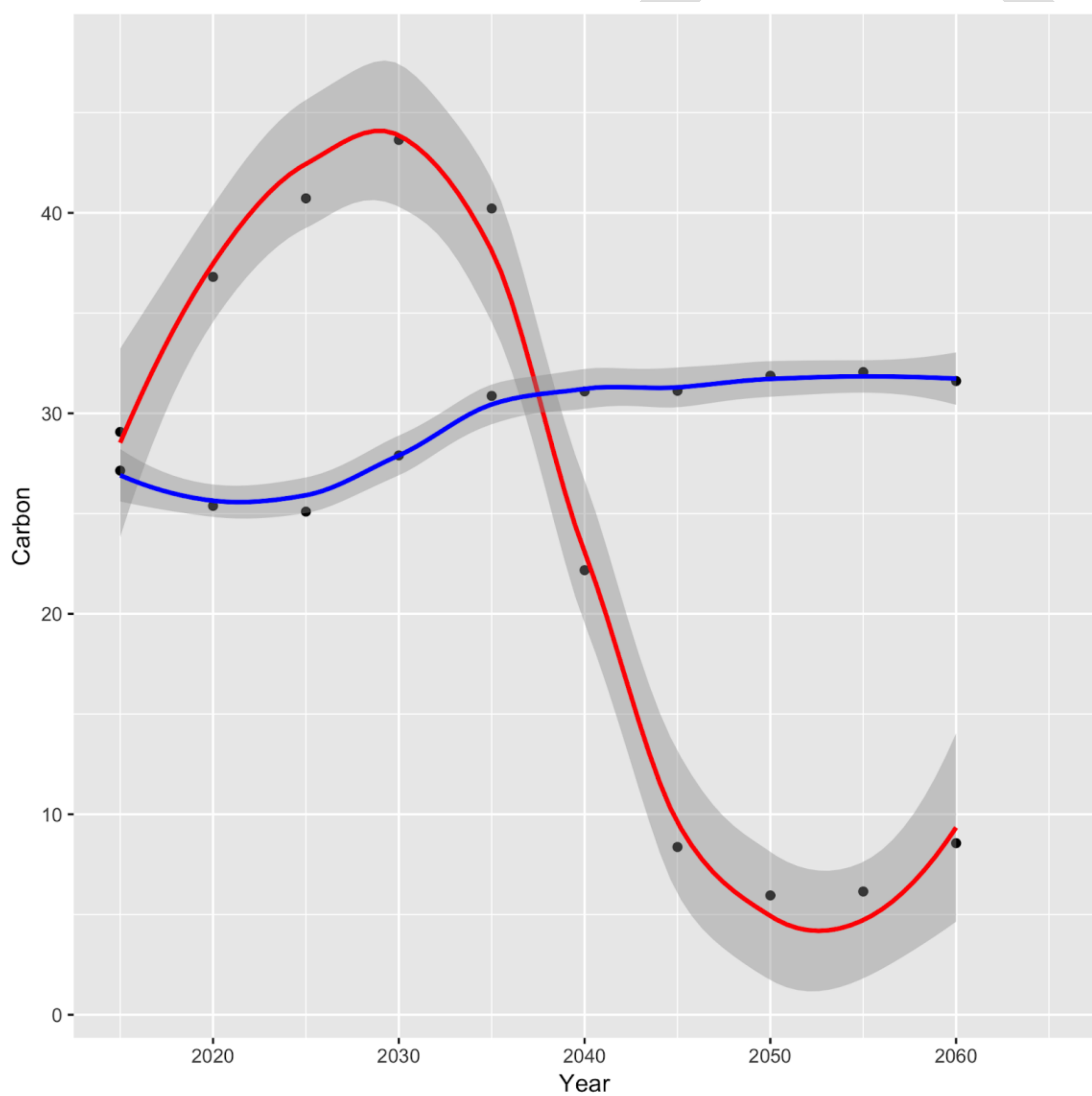


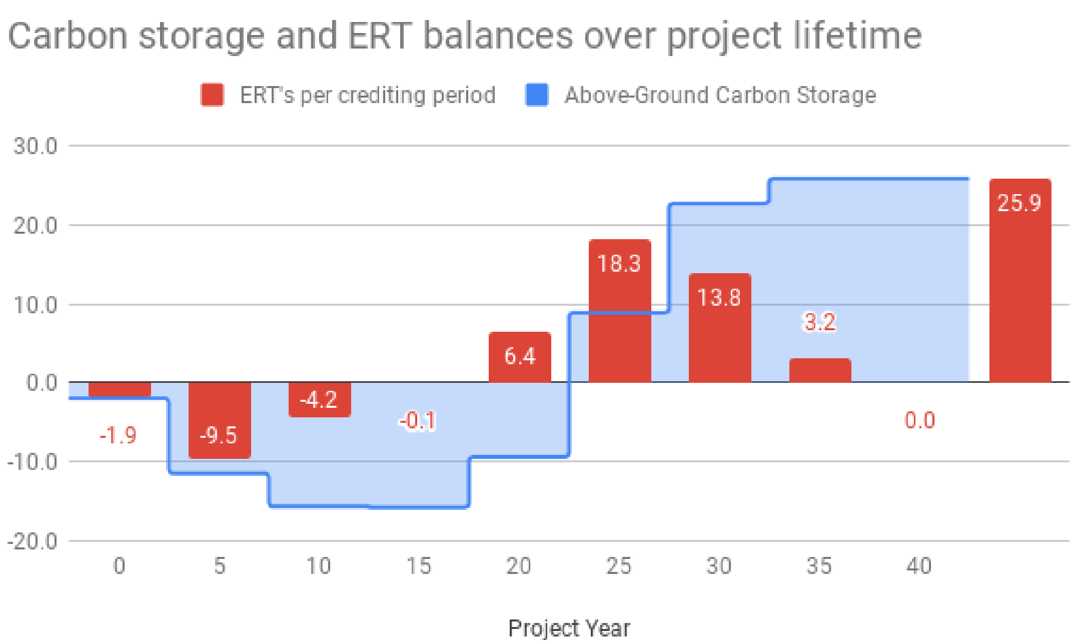
Figure 3: Project and Baseline Carbon Storage

Restoration treatments prevent the loss of carbon from high-severity fires and help secure existing carbon in healthier, more resilient forests. Restoration treatments are initially expected to reduce above-ground carbon storage through the removal of many small diameter trees from fuels reduction, thinning and prescribed fire activities. This loss of carbon is temporary as the trees remaining in restored stands continue to sequester carbon. Restored acres are also at a lower risk of experiencing high-severity fires and carbon reversals. Over the 40-year life of the project, carbon storage is expected to remain relatively stable around 32 tons per acre.

The baseline scenario of no restoration treatments shows an initial increase in carbon due to continued sequestration existing forests. However, this carbon is stored in small diameter trees, susceptible to high-severity fire. The volatility of carbon storage in the baseline scenario is clearly represented by the rapid loss of forests and forest carbon between year 25 and year 35. By year 25 the fire models predict that more than 80% of acres analyzed for this project will have burned in a high-severity fire. Over the 40-year life of the project 99% of acres are expected to experience high severity fire. These fires would result in the net loss of more than 30 ton per acre. In addition, fires will also cause a change in ecosystem type, moving from forest to shrub, grassland and chaparral ecosystems. Thus, the levels of carbon sequestration after fires are expected to be delayed and have less ability to provide long-term, stable carbon storage.

Economic Analysis

Above-ground carbon benefits average 25.9 tons of carbon per acre over the lifetime of the project. The carbon storage benefits are initially realized at year 20 year of the project and continue to aggregate until year 40. While this may pose challenges for issuing carbon credits, the modeling performed in the case study align with peer-reviewed literature and strongly suggest that restoration treatments may be necessary to ensure the persistence of ponderosa pine forest within the study area. The upfront investment in forest restoration will have significant carbon and ecological impacts.



Applying the estimate of 25.9 tons per acre across 37,677 acres that would experience treatments, this project could help store ~975,834 tons of above-ground carbon. Assuming 25% of carbon offsets are withheld in the buffer pool, a total of 731,815 tons of carbon are estimated to be available for purchase as voluntary offset market. The sale of ERTs at current market prices could generate from $3.6M to $14.6M. At current prices ERTs sell between $5 and $20. We use this range as a conservative estimate of what ERTs will sell for during the life of the project.

Table 5: Economic Impact of ERTs from CWPP

Price per ERT	Funds for restoration from sale of ERTs	Percentage of CWPP Restoration Costs ($16M)
$5	$3,659,378	23%
$10	$7,318,757	46%
$20	$14,637,514	91%

Assuming that restoration will cost the estimate $16M dollars (the high projection) this project could contribute between 23% and 91% of the project cost. With the addition of wood product value, reduced thinning costs, or increased ERT prices it is feasible that a carbon project would help make the implementation of the CWPP financially viable through the sale of ERTs.