

Demonstration of the Climate Action Reserve Forestry Protocols at LaTour Demonstration State Forest, Final Report

Timothy A. Robards and Doug Wickizer¹

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Summary

This project provides two case studies of improved forest management and reforestation projects using version 3.0 of the Climate Action Reserve (CAR) forest protocol. Public and private lands are considered as separate scenarios. The baselines, project activity and Certified Reserve Tonnes (CRT) additionality was calculated for 100-year time periods. An economic analysis is provided for each scenario. A fire risk modeling analysis was also conducted.

¹ California Department of Forestry and Fire Protection, Sacramento. Timothy A. Robards, Ph.D, RPF (Forest Biometrician), may be contacted at tim.robards@fire.ca.gov. Doug Wickizer, RPF (Staff Chief) may be contacted at doug.wickizer@fire.ca.gov.

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Overview of the Climate Action Reserve Forestry Protocols

Climate Action Reserve (CAR) is a private non-profit national offsets program headquartered in Los Angeles that focuses on regulatory-quality emissions reporting and reductions. CAR also accredits and oversees independent project verifiers. Verified reduction credits, which are serialized and tracked by CAR, are called Certified Reserve Tonnes or CRTs.

A project that has CRTs may, as of this writing, sell them on the voluntary over-the-counter market or hold them for later trading in either a voluntary market or as offsets under emerging cap and trade market mechanisms. Cap and trade programs are proposed and in various stages of development, including already active, at the state (i.e. California), regional (i.e. Western Climate Initiative (WCI), Regional Greenhouse Gas Initiative (RGGI)), national and international levels. The Voluntary Carbon Standard Association (VCS), an international standards group focused on project-based voluntary GHG reductions, has recognized CAR offsets as meeting their criteria for protocols, verification and tracking. This allows CRTs to also be traded as Voluntary Carbon Units (VCUs).

Two CAR protocols exist that are related to trees and forests; the Forest Project Protocol (version 2.1) and the Urban Forest Project Protocol (version 1.0). These are reporting protocols for use by project developers. Each reporting protocol has an associated verification protocol that is used by the third-party verifier. The Urban Forest Project Protocol has only one project type, tree planting and maintenance. The Forest Project Protocol has three project types; they are:

- Improved Forest Management
- Reforestation
- Conservation

This demonstration project includes examples of the forest management and reforestation project types. A fuels treatment analysis, not related to the current CAR protocols, is also included.

The CAR is in the process of a major revision (version 3.0) of the Forestry Project Protocols to address the following objectives.

- Allow greater landowner participation, particularly publicly-owned lands and industrial working forests.
- Make improvements that improve the protocol's clarity, accuracy, conservatism, environmental integrity, and cost-effectiveness (where doing so does not infringe on other principles).
- Design to allow use outside of California with minimal additional analysis.

The timing of the protocol revisions made it impossible to take this project through the verification process as these revisions were necessary to have a valid project on public lands. However, the timing of this report and associated products coinciding with the release of the revised protocols provides an excellent opportunity to use this project as a template for project developers. The rest of this section covers the specific guidelines for a reforestation and forest management project, data requirements, and permanence and leakage risk assessments.

The start date may go back to 2001 if the project is initiated within one year of the revised protocol approval, otherwise it may go back one year. Since this project is initiating in 2009 we can use 2005 as the starting year. A project implementation agreement must be done between the project developer and the Reserve when private lands only. There is a native species test and a requirement to maintain or increase on-site live pool carbon stocks. A project assessment boundary must be identified and a secondary-effects (leakage) assessment performed. This is to ensure that the project is not causing an effect that counteracts the sequestration occurring directly from the project.

Reforestation Project Type

Reforestation may be defined as being out of forest cover (10% threshold) for at least ten years or as having sustained a catastrophic event in the last ten years. The project has to have been in forest cover in the past. This project uses the definition of being out of forest cover for over ten years. Both public and private lands may use this project type.

A baseline must be established for the project. The baseline uses the current conditions and projects those into the future for 100 years using a qualitative assessment as the guide. The qualitative assessment is based on the likely outcome in the absence of the project.

As with all forest projects the CRTs are accrued after they have occurred. Since stand biomass generally follows a sigmoidal curve, most CRTs will be realized after the initial “lag” phase of stand development. For this reason, inventories are likely not profitable or reasonable to expect until later in the life of the stand.

Improved Forest Management Project Type

This project type may apply to private or public lands. The use of native species with natural forest management, as defined by the protocol, is required. The forest may or may not be managed for timber. As with the reforestation project type, a 100-year baseline must be established. The following steps are required to construct the baseline for the private lands scenarios.

1. Determine the applicable forest type to lookup the average stocking from the provided tables.

2. Look up the average per acre live biomass carbon stocking, which was derived from the USDA Forest Service Forest Inventory and Analysis (FIA) data.
3. Calculate the average per acre current carbon stocking for the live biomass in the project.
4. Decide if you are below or above the landscape-level average. How to calculate additionality will be based on this.
5. Check for additional constraints on management from legal, physical and economic feasibility perspectives. This may increase the baseline if more restrictive than current stocking levels or FIA average. This may be demonstrated by either an economic analysis or a demonstration that the baseline is consistent with activities in the previous 15 years, for the assessment area.
6. Model the baseline but do not drop below the legal, physical and economic limits.

The public lands baseline requires a more qualitative assessment up front before it can be quantified. Planning and budgets are part of this assessment.

Permanence Risk Analysis

Permanence is defined by the CAR as a period of 100 years. A risk analysis provides information to calculate a buffer pool requirement or alternatively private insurance against reversals of CRTs. A separate risk assessment is conducted for both of the projects under a private and public lands scenario. Appropriate reductions in the form of a buffer pool will be applied and carried through the economic analyses.

Leakage Risk Analysis

There are separate analyses for reforestation and forest management project types. For reforestation, an assessment of activity shifting leakage is required where crop lands or grazing is an issue. Using the flowchart provided it is quickly determined that the leakage risk is zero for reforestation. Decreases in harvest amounts over the 100-year period relative to the baseline is multiplied by 20% to derive the penalty for leakage on improved forest management projects.

Demonstration Projects

Two contiguous areas within LaTour Demonstration State Forest (LDSF) were considered as separate projects for the purposes of this demonstration. The projects were treated as public and private lands in separate scenarios, so that the implications to CRTs and the economics could be compared. Figure 1 shows the locations of the project areas on the Forest. LDSF is located in Shasta County in the Southern Cascade Mountains. The Forest is at the headwaters of the South Cow Creek drainage, which

eventually flows into the Sacramento River. White fir and mixed conifer are the primary forest types with some ponderosa/Jeffery pine types where planting has occurred.

The Forest was acquired in an essentially uncut condition in 1946 with single tree harvesting that focused on improving forest health commencing in the 1950s. Small group selection harvests were started in the 1990s to begin to regenerate mature forest and to address pest issues. A wildfire (Whitmore Fire) burned approximately 500 acres of the lower end on the west side in 1978 (figure 2). Salvage operations occurred at that time and the area was planted. Shrub competition severely retarded the growth of the regeneration, either slowing conifer growth or killing the trees (figure 3). Some portions of the Forest have been brush fields for as long as the State has had the property. Some of these are around McMullen Mountain and some of the area burned in 1978 was in brush.

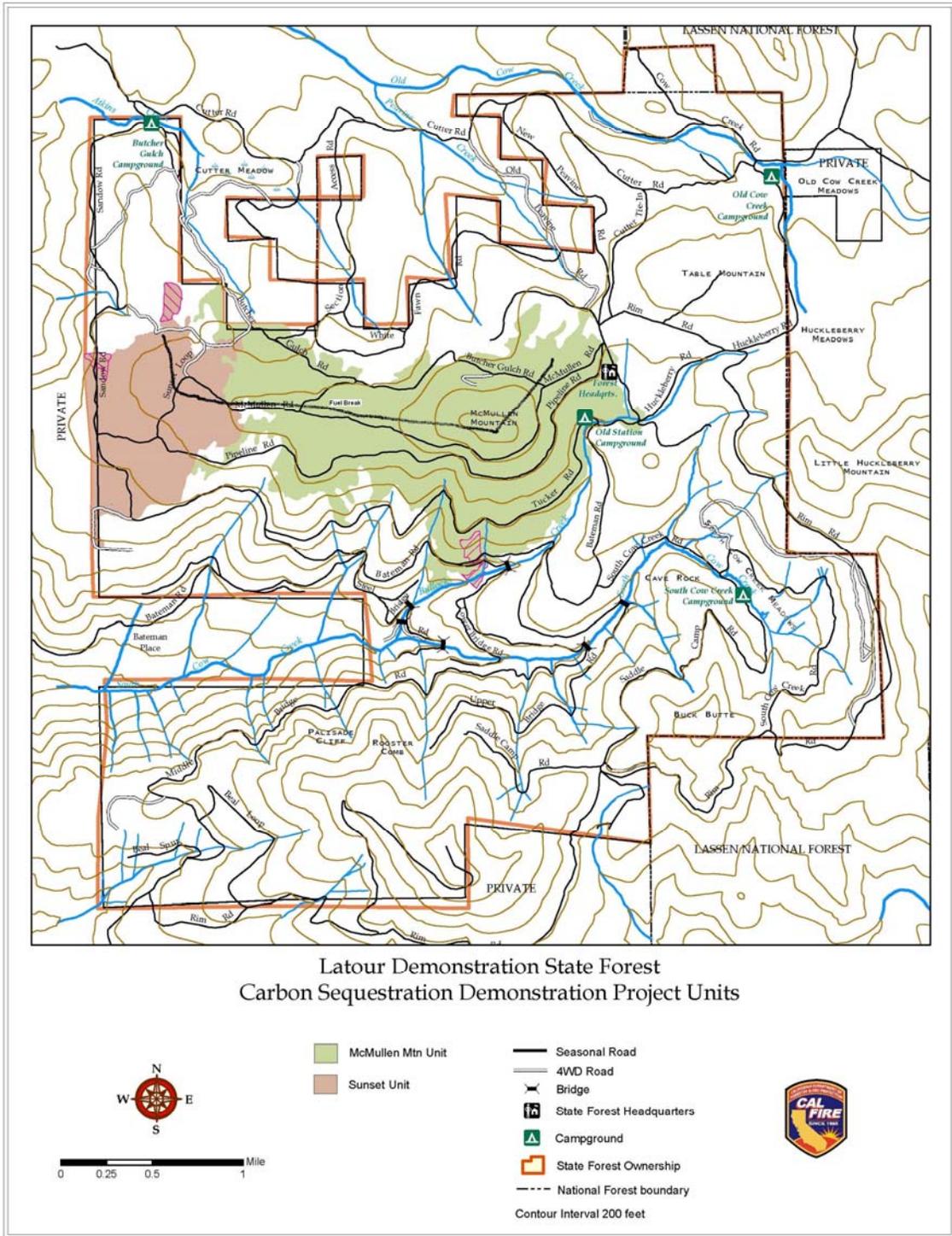


Figure 1. Map of LaTour Demonstration State Forest showing the two project areas.

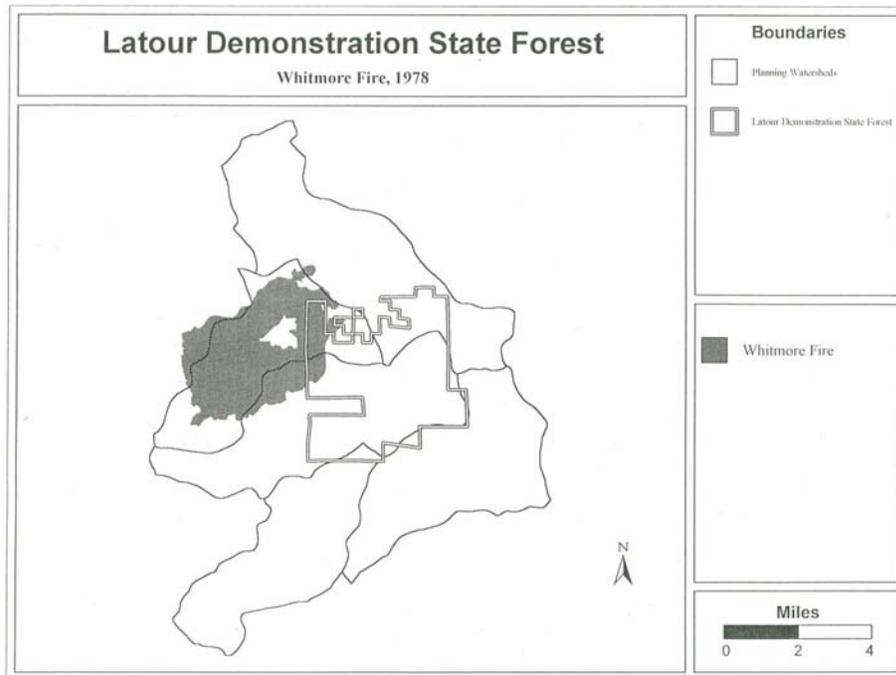


Figure 2. Whitmore (1978) fire boundary showing extent onto LDSF.



Figure 3. Example of 1978 Whitmore burn in 2007 showing mix of survivor trees, planted pine regeneration, competing shrubs and naturally seeded white fir regeneration.

A number of areas were treated as part of this project (figure 4). Approximately 200 acres were treated (table 1). Units 2, 5 and a corner of 4 were the reforestation areas, but most of the treatments were improved forest management that fully occupied the sites with conifers and improved stand growth.

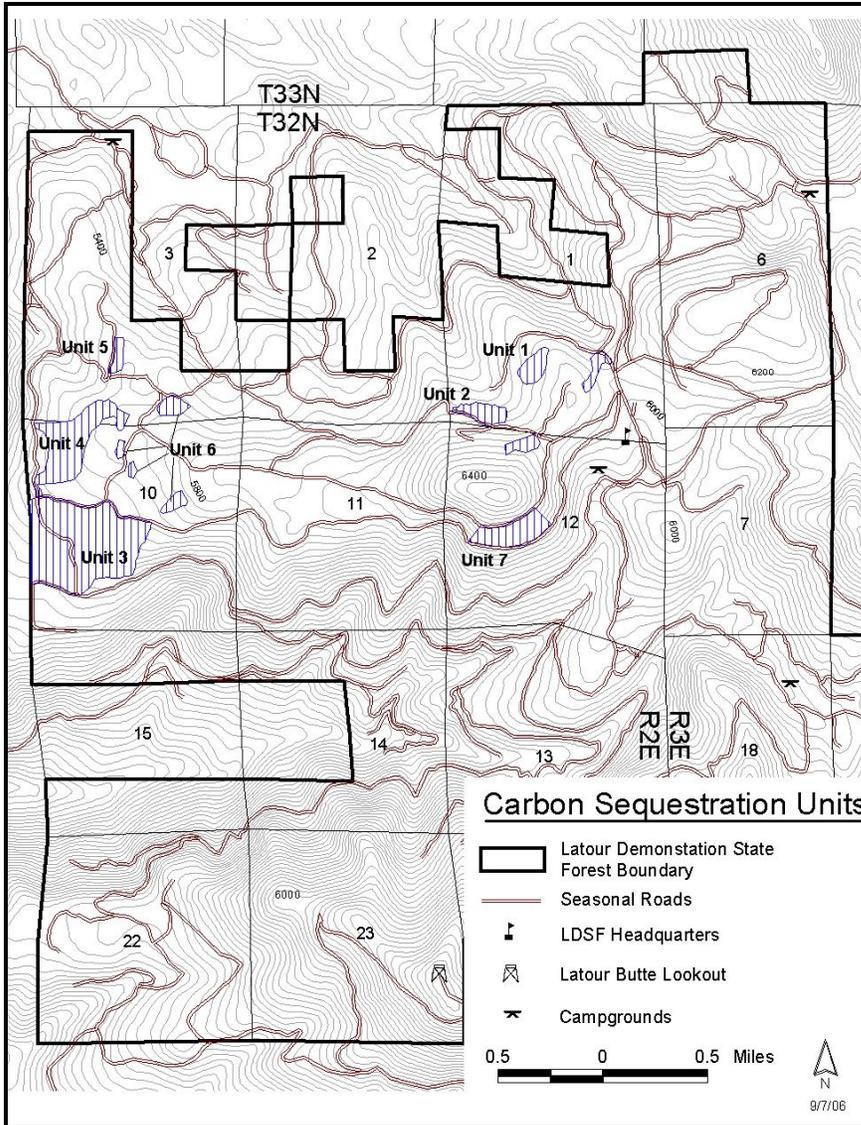


Figure 4. Treatment units, except unit 7 which was not installed. Units 2, 5, and part of 4 are the regeneration units.

Table 1. Treatment descriptions.

UNIT #	LOCATION	ACREAGE (APPROXIMATE)	TYPE OF WORK	START
1	OLD PEAVINE SPUR (SE/4Sec. 1)	20 acres	Brush piling, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
2	UPPER BUTCHER GULCH ROAD (SW/4, Sec. 1)	20 acres	Brush Mastication, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
3	SANDOW RD. TO PIPELINE RD (Sw/4, Dec. 10)	80 acres	Brush Release/Hand Spray	June to October 2007
4	BETWEEN SANDOW		Release hand	June to October 2007

	RD. AND SUNSET RD. (NW/4, Sec. 10)	35 to 40 acres	spray of 2000 Brush piled Unit	
5	SPUR ROAD OFF SANDOW RD.(NW/4 of SE/4, Sec. 10)	7 to 10 acres	Brush piling, Spraying, Planting	June 2007 Spray spring 2008 Plant Fall 08/Spring09
6	SCATTERED SMALL GROUPS OPENINGS BETWEEN McMULLEN RD. AND TUCKER RD.	20 to 25 acres	Hand spray	June 2007

Sunset Project Description

This unit is on the west side of the Forest, is about 428 acres (173 hectares) at 40.656° N and 121.743° W. The unit has an average elevation of 5,544 feet (1,690 m) with a range of 5,369 feet (1,636 m) to 5,749 feet (1,752 m) and has a relatively high ponderosa pine (*Pinus ponderosa*) component relative to the other mixed conifer species, partly due to the planting that occurred after the 1978 Whitmore Fire. The other dominant conifer species are sugar pine (*Pinus lambertiana*), incense-cedar (*Calocedrus decurrens*), white fir (*Abies concolor*), and red fir (*Abies magnifica*). The average climate (PRISM 2009) from 1971 through 2007 for this unit was 58.4 inches (148 cm) precipitation falling as rain and snow with an average January daily minimum temperature of 24.8° Fahrenheit (-4.0° C) and average July daily maximum temperature of 82.5° Fahrenheit (28.1° C). Table 2 shows the acres (table 3, hectares) by forest type and project type.

Table 2. Acres for each unit by forest type and project type.

Forest Type	Sunset			McMullen Mtn.		
	Reforestation	Management	Total	Reforestation	Management	Total
Ponderosa Pine	10.2	243.6	253.8	0.0	30.5	30.5
Mixed Conifer	0.0	7.8	7.8	8.5	104.4	112.9
White Fir	0.0	174.4	174.4	10.1	1,010.1	1,020.2
Red Fir	0.0	0.0	0.0	0.0	47.1	47.1
Total	10.2	425.8	436.0	18.6	1,192.1	1,210.7

Table 3. Hectares for each unit by forest type and project type.

Forest Type	Sunset			McMullen Mtn.		
	Reforestation	Management	Total	Reforestation	Management	Total
Ponderosa Pine	4.1	98.6	102.8	0.0	12.3	12.3
Mixed Conifer	0.0	3.2	3.2	3.4	42.3	45.7
White Fir	0.0	70.6	70.6	4.1	408.9	413.0
Red Fir	0.0	0.0	0.0	0.0	19.1	19.1
Total	4.1	172.4	176.5	7.5	482.6	490.2

McMullen Mountain Project Description

This unit (figures 5 - 7) is centered on McMullen Mountain in the north/center of the Forest, is about 1,211 acres (490 hectares) at 40.640° N and 121.703° W. The unit has an average elevation of 5,850 with a range of 4,970 feet (1,515 m) to 6,411 feet (1,954 m) and is dominated by white fir stands. The average climate

(PRISM 2009) from 1971 through 2007 for this unit was 56.1 inches (142 cm) precipitation falling mostly as rain and snow with an average January daily minimum temperature of 23.8° Fahrenheit (-4.6° C) and average July daily maximum temperature of 81.4° Fahrenheit (27.4° C). Table 2 shows the acres (table 3, hectares) by forest type and project type.



Figure 5. White fir stand that grew up through shrubs through natural succession over many decades; shrub “skeletons” are visible on ground.



Figure 6. Before mastication treatment of reforestation unit on McMullen Mountain. Evidence of past burning in unit, which may explain lack of advanced regeneration.



Figure 7. Post treatment of reforestation unit on McMullen Mountain showing mastication and planted seedling.

Sunset Project GHG Analysis: Private Land Scenario

This project is mostly a forest management project (tables 2 and 3). The protocols specify that the required carbon pools for a forest management project are the above- and below-ground living biomass, standing and down dead biomass (note that down dead biomass was changed to optional in the final version), and off-site dead biomass. The optional pools are shrubs and herbaceous understory, litter, and soil carbon. Only the required pools will be included in this analysis. The reforestation unit in this project also requires that shrubs and herbaceous understory be estimated. The above- and below-ground live tree biomass is required for reforestation where they exist. They are rarely present for this unit and will be tracked at future inventory periods (figures 8 to 10).



Figure 8. Reforestation unit in Sunset Project, pre-treatment.



Figure 9. Reforestation unit in Sunset Project showing dead brush and exposed mineral soil with planted conifers post-treatment.

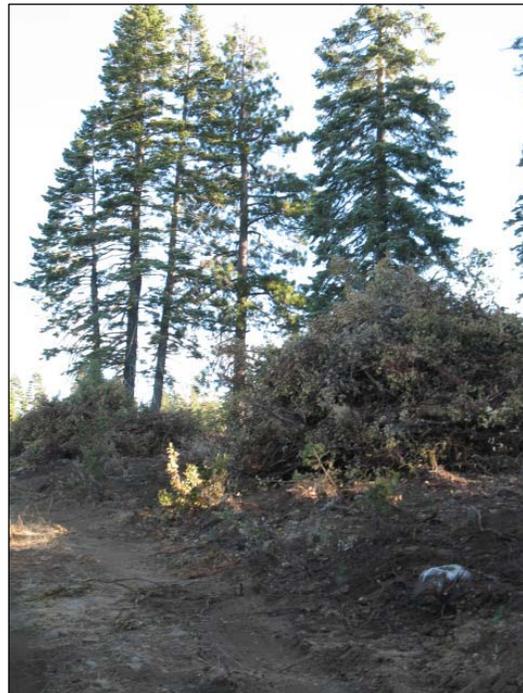


Figure 10. Reforestation unit in Sunset Project showing grove of residual trees near road post-treatment.

Inventory Description and Results

The inventory design and calculation methods are described in appendix I. Table 4 shows the starting carbon inventory estimate for the project along with the percent error. The protocol specifies that a reduction in CRTs occur for percent errors between 5% and 20%. Since the percent error is less than 5% there are no deductions.

Table 4. Starting carbon inventory for forest management on the Sunset project.

Attribute	Reforestation	Forest Management
No. of Plots	3	141
Mean Trees per Acre	0	95.60
Mean Trees per Hectare	0	236.14
Mean Bole Cubic Feet per Acre (ground to tip)	0	614.41
Mean Bole Cubic Meters per Hectare (ground to tip)	0	1,517.58
Mean Bole C per Acre (tonnes)	0	18.96
Mean Bole C per Hectare (tonnes)	0	46.84
Mean Bark C per Acre (tonnes)	0	8.97
Mean Bark C per Hectare (tonnes)	0	22.15
Mean Crown Branches C per Acre (tonnes)	0	4.17
Mean Crown Branches C per Hectare (tonnes)	0	10.29
Mean Tree Live Aboveground C per Acre (tonnes)	0	32.37
Mean Tree Live Aboveground C per Hectare (tonnes)	0	79.95
Mean Tree Live Belowground C per Acre (tonnes)	0	11.19
Mean Tree Live Belowground C per Hectare (tonnes)	0	27.65
Mean Tree Live C per Acre (tonnes)	0	43.57
Mean Tree Live C per Hectare (tonnes)	0	107.63
Acres	10.2	425.8
Hectares	4.1	172.4
Total Live Tree C (tonnes)	0	18,248.55
Total Lying Dead C (tonnes)	0.04	0.89
Total Standing Dead C (tonnes)	0.14	3.38
Total C (tonnes)	0.18	18,252.82
Standard Error C (tonnes)	na	871.74
Percent Error of C (%)	na	4.78%
Mean Shrub Aboveground C per Acre (tonnes)	14.60	na
Mean Shrub Aboveground C per Hectare (tonnes)	36.06	na
Mobile Combustion C per Acre (tonnes)	0.12	na
Mobile Combustion C per Hectare (tonnes)	0.29	na
Total Shrub Aboveground C (tonnes)	148.92	na
Total Reforestation C (tonnes)	150.29	na

Baseline Calculations

The baseline for the reforestation project type is the existing aboveground shrub carbon, which will be assumed to be a steady stock for the 100-year projection period. In this case it is 148.92 tonnes of C, which is 14.6 tonnes C per acre (36.1 t/h). No dead wood is assumed since the area was a brush field and no large dead wood was accumulating. No harvests were simulated. The reforestation unit is a brushfield that will undergo a slow natural succession process if left undisturbed. Given the fire frequency for the area and

the high fuel load and combustion potential of this fuel type, a high-severity disturbance would be likely in a 100-year timeframe. There are no legal requirements to reforest this unit.

The baseline for forest management project types bifurcates depending on whether the starting stocks of carbon are above or below the average for the applicable assessment area (common practice), based on the FIA average. LDSF is located in the Sierra Nevada – Southern Cascades assessment area, which is 39 tonnes per acre in above- and below-ground live trees for private ownerships. Since the inventory shows 43.57 tonnes per acre in total live tree carbon, the forest management baseline shall be based on a steady flow from the FIA mean of 39 tonnes per acre. The current inventory will be the starting condition, which is 2005 in this case since that is when the project starts. The resulting baseline will have to be shown to be economically and legally feasible, which it is given that there are not significant constraints to management of the unit. The resulting average stocks over a 100-year period must be at or above the common practice figure of 39 tonnes per acre C.

If a harvest schedule uses optimization, such as a linear program, and the carbon yields are incorporated into it then the baseline may be easily modeled by changing the optimization function to match the FIA baseline figure. Otherwise, and this is the case here, modeling the harvest schedule must be done by trial and error to approach the FIA figure but end at or above it. In general, the clearfelling, whether as small group selections less than or equal to 2.5 acres (1 hectare) or clearcuts up to 20 acres (8 hectares) in size, was moved up in time and commercial thinnings with a residual basal area of 100 ft²/acre (22.9 m²/h) were used to maintain the stocking over time. These opening sizes and residual stocking meet the minimum requirements of the California forest practice regulations. Where clearcuts were implemented the minimum age requirements of the rules were met. Table 5 shows a summary of the silvicultural treatments simulated for the baseline.

Table 5. Acres of silvicultural prescriptions for the baseline simulation of the Sunset Unit for private lands forest management.

Treatment	Year										
	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Clearfell (Group Selection and Clearcut)	69.7	12.3	6.4	34.9	69.5	0.0	16.0	2.0	203.4	10.9	0.0
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	14.1	0.0	57.2	252.9	261.0	269.3	312.4	144.2	166.2	31.1
Commercial Thin with 120 sq. ft. Residual Basal Area	0.0	0.0	0.0	9.5	0.0	0.0	0.0	0.0	22.0	0.0	0.0
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	65.6	22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	4.5	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Single Tree Selection with 70% Basal Area Retention	0.0	0.0	0.0	117.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitation and Salvage	0.0	52.7	0.0	44.8	0.0	18.9	0.0	6.2	0.0	0.0	0.0
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	0.0	0.0	19.1	0.0	19.1	0.0	19.1	0.0	19.1	0.0

The amount of carbon associated with the live and dead wood, on-site and off-site, for the baseline is shown in table 6. Although the landfill pool is not used for additionality calculations it is required to report it. Figures 11 and 12 show the on-site and off-site baseline estimates for the 100-year planning period. Note that the year 2010 is the only 5-year reporting with the rest being 10-year periods. When averaging the baseline only the 10-year periods were used.

Table 6. Tonnes per acre of carbon in the baseline and project activity projections for the Sunset Unit forest management scenario.

Year	Baseline									Project					
	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	FIA Live Tree Average	On-site Live and Dead C Baseline	On-site Live and Dead C Avg Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	42.86	6.67	40.88	39.00	49.53	46.34	1.03	0.68	0.17	42.86	8.25	51.11	0.00	0.00	0.00
2010	31.23	5.56	40.88	39.00	36.79	46.34	1.82	0.68	0.29	33.31	6.92	40.24	1.10	1.10	0.18
2015	38.16	5.82	40.88	39.00	43.98	46.34	2.22	1.36	0.36	48.42	6.92	55.34	1.53	0.44	0.25
2025	54.66	8.32	40.88	39.00	63.01	46.34	4.30	1.36	0.69	66.46	8.36	74.82	3.41	1.88	0.55
2035	53.25	7.54	40.88	39.00	60.79	46.34	6.58	1.36	1.06	68.51	7.67	76.18	3.71	0.30	0.60
2045	41.50	5.37	40.88	39.00	46.87	46.34	7.60	1.36	1.22	88.79	6.74	95.54	6.16	2.45	0.99
2055	45.25	6.04	40.88	39.00	51.29	46.34	8.70	1.36	1.40	75.37	6.82	82.19	6.44	0.27	1.03
2065	50.29	6.67	40.88	39.00	56.96	46.34	9.74	1.36	1.56	93.63	7.11	100.74	8.56	2.12	1.37
2075	53.60	8.72	40.88	39.00	62.32	46.34	12.70	1.36	2.04	85.22	7.94	93.15	8.83	0.27	1.42
2085	18.91	3.48	40.88	39.00	22.39	46.34	13.41	1.36	2.15	102.02	8.98	111.00	11.05	2.21	1.77
2095	19.36	3.54	40.88	39.00	22.93	46.34	13.49	1.36	2.17	90.40	8.81	99.21	11.28	0.23	1.81
2105	31.80	7.44	40.88	39.00	39.24	46.34	13.63	1.36	2.19	104.93	8.94	113.88	11.39	0.11	1.83

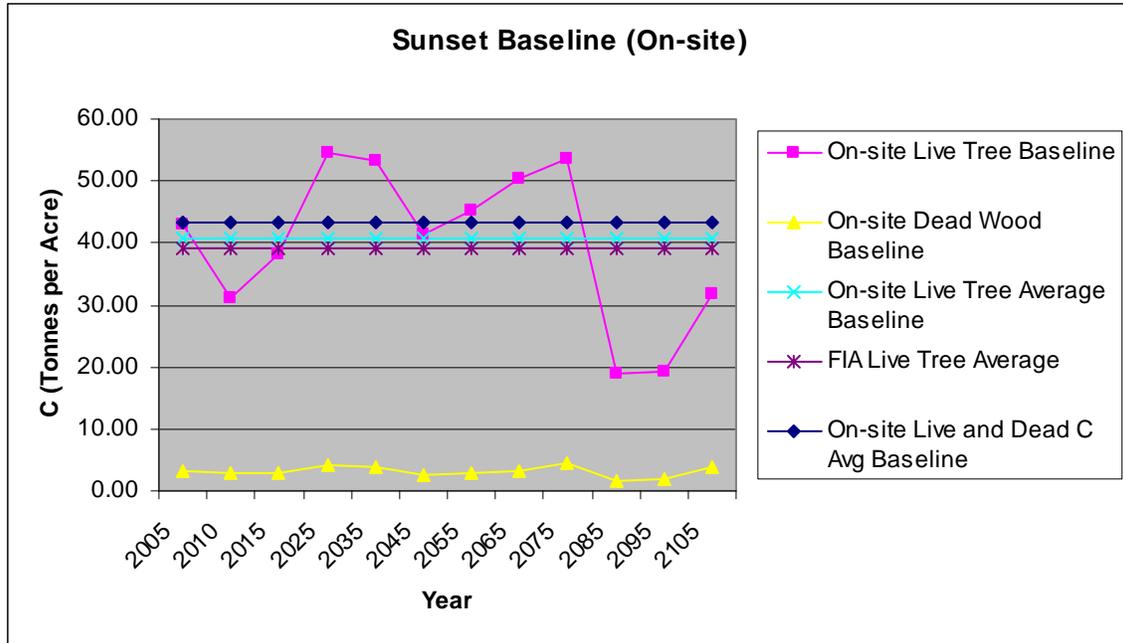


Figure 11. Sunset unit on-site baseline for private lands forest management scenario.

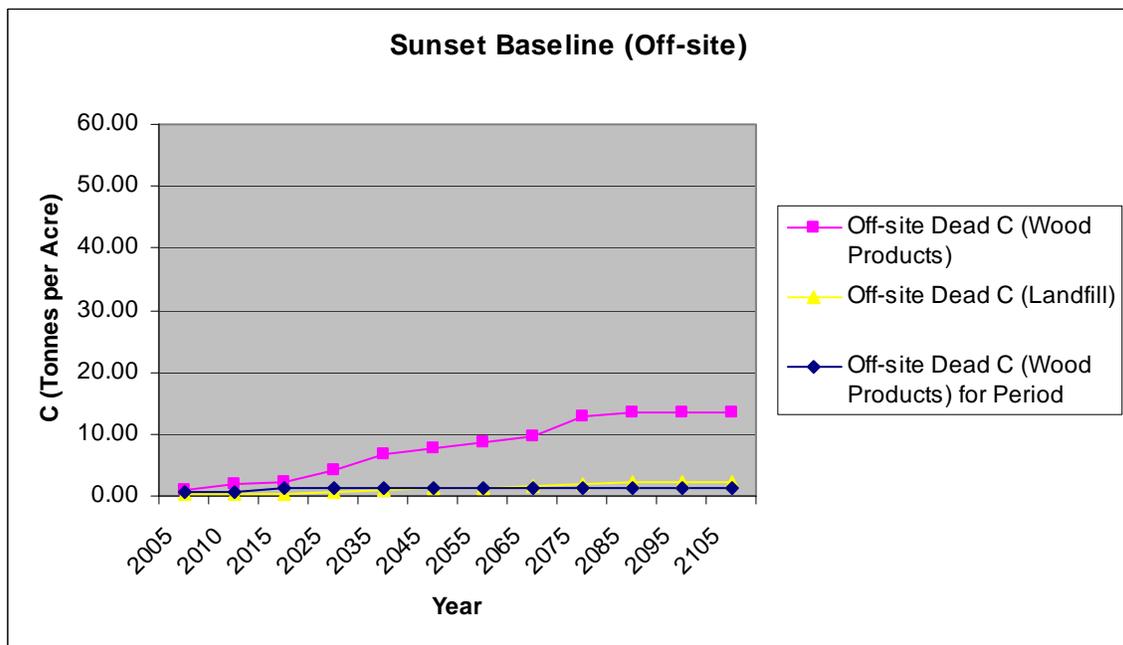


Figure 12. Sunset unit off-site baseline for private lands forest management scenario.

The results of the forest management baseline analysis were that the average on-site stocking was 40.88 tonnes of C per acre (100.97 tonnes C per hectare). Off-site wood products storage (based on 100-year storage in-use) increased over time and had an average over the period of 0.136 tonnes/acre/year C. This equated to a total of 3,765 thousand cubic feet (106,600 m³) of timber over the 100-year period. Assuming six board

feet per cubic foot, this equates to 22,590 MBF total or 531 board feet per acre per year over the 100-year period.

Project Activity Calculations

The project activity for the reforestation project type was modeled as a 10x10 foot spacing of 1-0 planted seedlings of a pine and fir mix, which resulted in 436 trees per acre (1,077 trees/h). Commercial thinnings from below leaving a residual basal area of 120 ft²/ac (27.5 m²/h) were simulated in 2050, 2070, and 2090. The result of the project activity was to increase on-site carbon stocks to 76.3 tonnes C per acre (188.5 t/h) after 100 years (table 7). The total wood products pool (figure 13) projected over the 100-year period was 11.9 tonnes C per acre (29.4 t/h), which was 7.8 thousand cubic feet (MCF) per acre (546 m³/h).

Table 7. Tonnes per acre of carbon in the baseline and project activity projections for the Sunset Unit reforestation scenario.

Year	Baseline					Project					
	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	14.60	0.00	14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2015	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2025	14.60	0.00	14.60	0.00	0.00	19.31	4.40	23.71	0.00	0.00	0.00
2035	14.60	0.00	14.60	0.00	0.00	47.76	4.40	52.16	0.00	0.00	0.00
2045	14.60	0.00	14.60	0.00	0.00	61.13	4.40	65.53	0.00	0.00	0.00
2055	14.60	0.00	14.60	0.00	0.00	49.78	2.80	52.58	4.02	4.02	0.64
2065	14.60	0.00	14.60	0.00	0.00	72.19	2.80	74.99	4.02	0.00	0.64
2075	14.60	0.00	14.60	0.00	0.00	55.56	2.80	58.36	8.84	4.83	1.42
2085	14.60	0.00	14.60	0.00	0.00	69.59	5.80	75.39	8.84	0.00	1.42
2095	14.60	0.00	14.60	0.00	0.00	60.12	5.80	65.92	11.92	3.08	1.91
2105	14.60	0.00	14.60	0.00	0.00	70.50	5.80	76.30	11.92	0.00	1.91

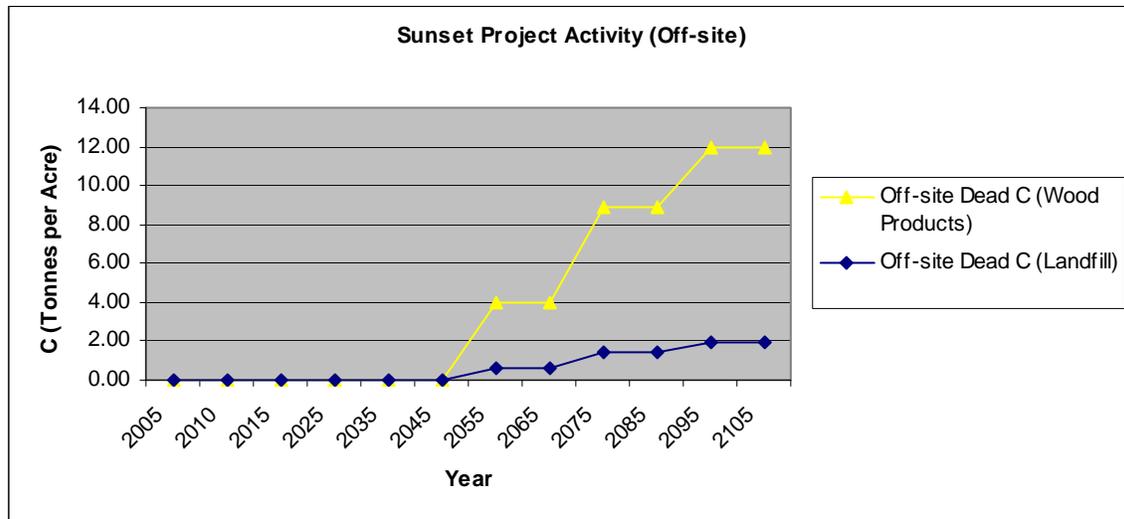


Figure 13. Reforestation project activity projections of off-site dead wood pools.

The project activity for the forest management project type was projected using the stand level treatments identical to the long-term harvest schedule approved by the State of California under 14 CCR 933.11(a), also known as an “option a” plan. Table 8 shows the silvicultural prescriptions. The results of the C stocking may be seen in table 6 under “Project”. Notice that there is a near-term decrease in carbon stocks, which is a reflection of the near-term harvesting that has occurred in this unit as per the existing harvest schedule. An approximate 20-year cutting cycle is implemented on LDSF. This will have an effect on the additionality calculation that is shown below.

The result of the project activity projection was to increase on-site carbon stocks from an average of 42.86 tonnes/acre (105.9 tonnes/hectare) to 104.93 tonnes/acre (259.2 tonnes/hectare) at the end of the 100-year period. Off-site wood products storage grew to 11.93 tonnes/acre C (29.5 t/h), which was 12 percent less than the 13.63 tonnes/acre C (33.7 t/h) in the baseline. The harvest is projected to total 3,146 MCF (89,088 m³) of timber over the 100-year period. Figures 14 and 15 show the project activity for the on-site and off-site carbon over time.

Table 8. Acres of silvicultural prescriptions for the project activity simulation of the Sunset Unit for private lands forest management.

Treatment	Year										
	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Clearfell (Group Selection and Clearcut)	0.0	90.4	6.4	21.7	6.5	21.8	6.4	17.1	6.3	11.9	3.3
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	13.1	0.0	15.8	0.0	60.7	0.0	39.1	0.0	61.2	0.0
Commercial Thin with 120 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	6.9	0.0	6.9	0.0	6.9	0.0
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	0.0	25.8	70.5	27.8	58.1	27.8	84.3	28.0	69.1	31.1
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	4.5	0.0	22.0	0.0	22.0	0.0	22.0	0.0	22.0	0.0
Commercial Thin with 180 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.7	0.0
Commercial Thin with 200 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7	0.0	0.0	0.0
Single Tree Selection with 70% Basal Area Retention	0.0	20.3	0.0	143.1	0.0	143.1	0.0	137.3	0.0	143.1	0.0
Sanitation and Salvage	0.0	65.5	0.0	59.7	0.0	31.7	0.0	37.5	0.0	31.7	0.0
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	0.0	0.0	19.1	0.0	19.1	0.0	19.1	0.0	19.1	0.0

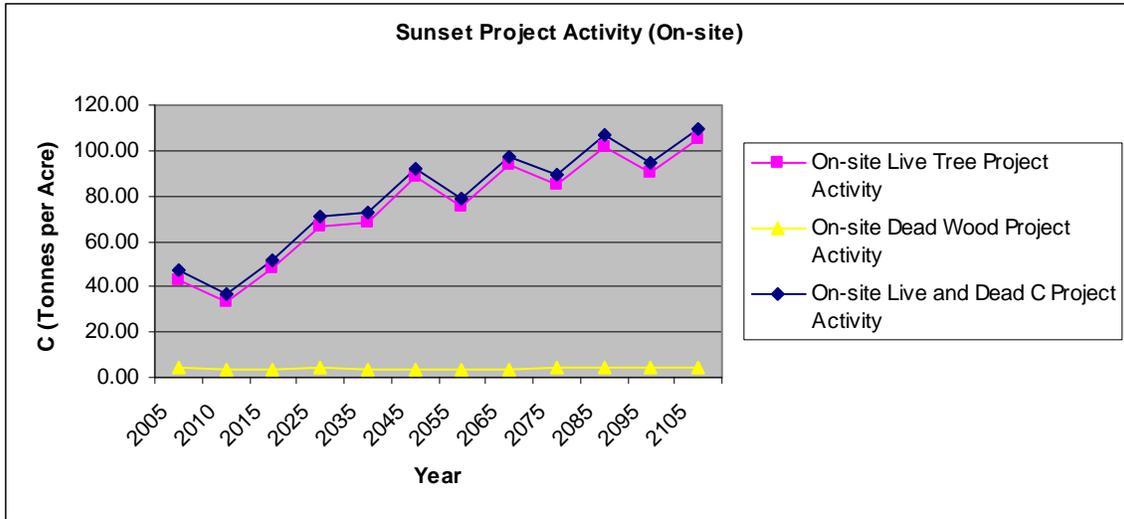


Figure 14. Sunset unit on-site project activity for the forest management project type.

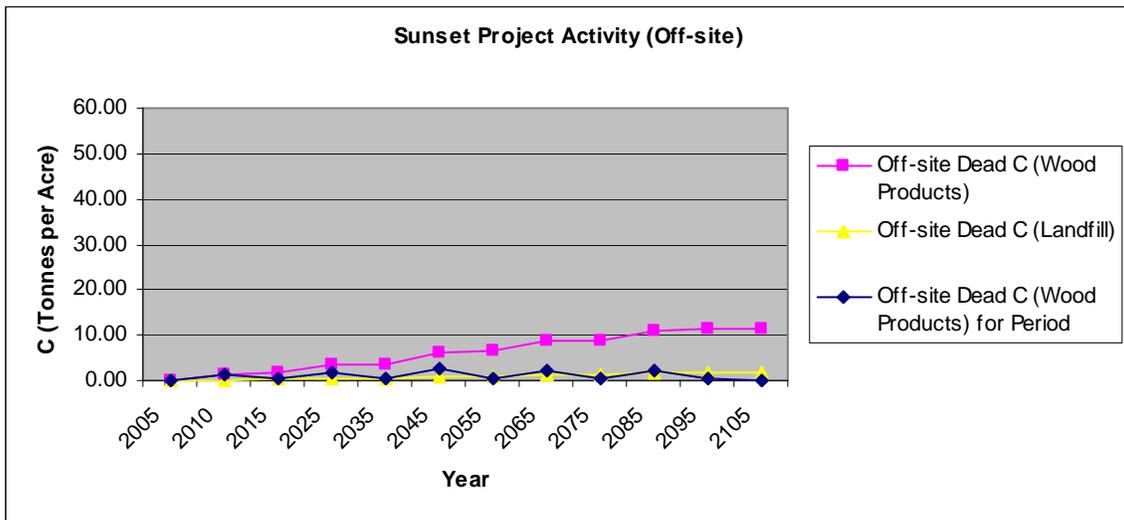


Figure 15. Sunset unit off-site project activity for the forest management project type.

Gross Biological Additionality

The difference between the project activity and baseline projections is the gross additionality, which is shown in tables 9 and 10 for the 100-year planning period and the two project types. Figures 16 and 17 show the gross additionality and the “smoothed” additionality whereby a reversal due to near-term harvests does not occur. This leads to an estimate of the decadal gross new CRTs, before any deductions for inventory precision, permanence or leakage.

Table 9. Tonnes of carbon in the gross additionality before deductions, deductions, and net additionality; for the Sunset Unit reforestation scenario.

Year	Gross Additionality						Deductions			Net Additionality			
	On-Site Additionality	Off-site Dead C Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	9.11	0.00	9.11	23.71	9.11	9.11	0.00	0.00	1.82	7.29	7.29	1.82	1.82
2035	37.56	0.00	37.56	13.85	37.56	28.45	0.00	0.00	5.69	22.76	30.05	5.69	7.51
2045	50.93	0.00	50.93	37.08	42.00	4.44	0.00	0.00	0.89	3.55	33.60	0.89	8.40
2055	37.98	4.02	42.00	4.92	42.00	0.00	0.00	0.00	0.00	0.00	33.60	0.00	8.40
2065	60.39	0.00	64.41	59.49	52.60	10.61	0.00	0.00	2.12	8.49	42.08	2.12	10.52
2075	43.76	4.83	52.60	-6.89	52.60	0.00	0.00	0.00	0.00	0.00	42.08	0.00	10.52
2085	60.79	0.00	69.63	76.52	63.24	10.64	0.00	0.00	2.13	8.51	50.59	2.13	12.65
2095	51.32	3.08	63.24	-13.28	63.24	0.00	0.00	0.00	0.00	0.00	50.59	0.00	12.65
2105	61.70	0.00	73.62	86.90	73.62	10.38	0.00	0.00	2.08	8.30	58.90	2.08	14.72

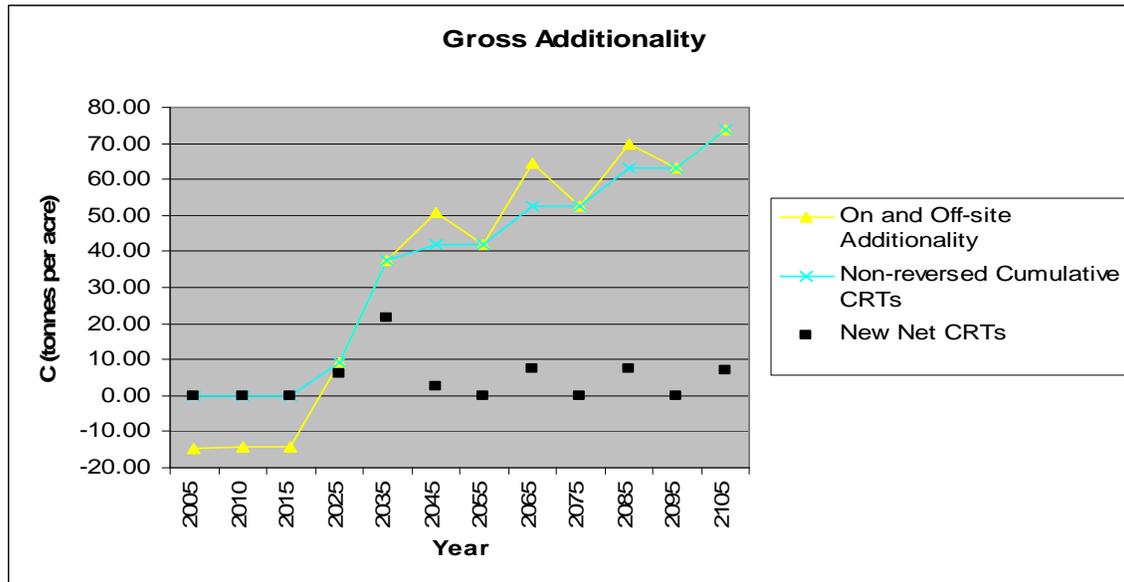


Figure 16. Reforestation, Sunset unit gross additionality and CRTs.

Table 10. Tonnes of carbon in the gross additionality before deductions, deductions, and net additionality; for the Sunset Unit forest management scenario.

Year	Gross Additionality						Deductions			Net Additionality			
	On-Site Additionality	Off-site Dead C Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	4.77	-0.68	4.09	4.09	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
2010	-6.10	0.42	-6.37	-10.46	0.00	0.00	-0.08	0.00	0.00	0.00	0.00	0.00	0.00
2015	9.00	-0.93	7.81	18.27	7.81	7.81	-0.16	0.00	1.56	6.09	6.09	1.56	1.56
2025	28.48	0.52	27.80	9.53	27.80	19.99	-0.16	0.00	4.00	15.83	21.92	4.00	5.56
2035	29.84	-1.06	28.10	18.57	28.10	0.30	-0.16	0.00	0.06	0.08	22.00	0.06	5.62
2045	49.20	1.09	48.55	29.98	34.11	6.01	-0.16	0.00	1.20	4.65	26.65	1.20	6.82
2055	35.85	-1.09	34.11	4.13	34.11	0.00	-0.16	0.00	0.00	0.00	26.65	0.00	6.82
2065	54.40	0.76	53.42	49.28	44.74	10.63	-0.16	0.00	2.13	8.34	35.00	2.13	8.95
2075	46.81	-1.09	44.74	-4.54	44.74	0.00	-0.16	0.00	0.00	0.00	35.00	0.00	8.95
2085	64.66	0.85	63.44	67.98	50.52	5.77	-0.16	0.00	1.15	4.46	39.46	1.15	10.10
2095	52.87	-1.13	50.52	-17.47	50.52	0.00	-0.16	0.00	0.00	0.00	39.46	0.00	10.10
2105	67.54	-1.25	63.93	81.40	63.93	13.42	-0.16	0.00	2.68	10.57	50.03	2.68	12.79

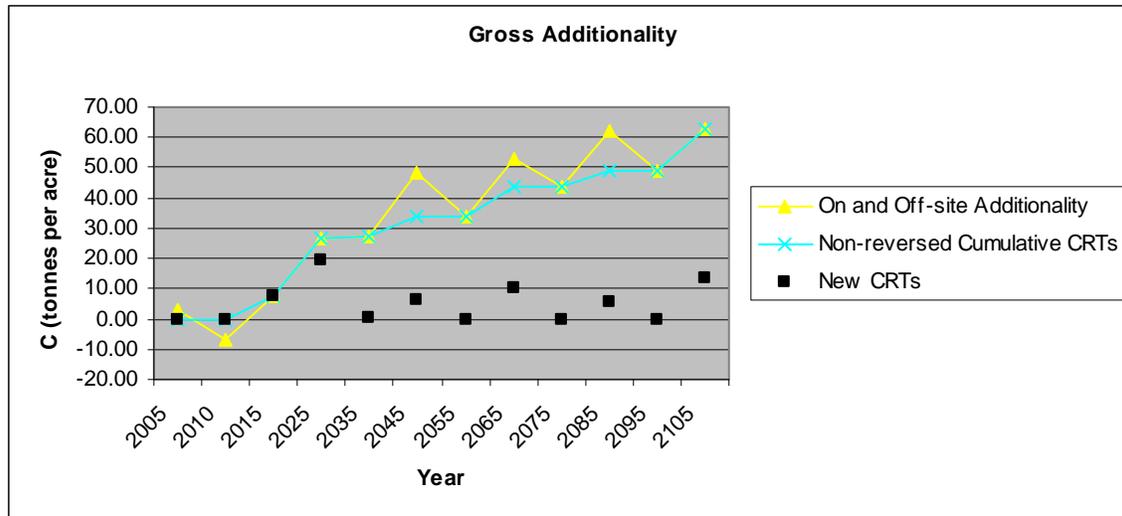


Figure 17. Forest management, Sunset unit gross additionality and CRTs.

Permanence Analysis

This is a risk analysis with the details provided in appendix D of the protocol. The analysis is identical for the reforestation and improved forest management project types.

Financial Risk: The financial risk for this private lands scenario assumes a PIA only and no conservation easement, which requires a 5% buffer contribution.

Management Risk: Management risk consists of three types of risks. Illegal removals are given a 0% risk for property in the United States. Conversion to an alternate land use is a function of whether development rights are encumbered by an easement or deed restriction, which is not the case here, incurring a 2% deduction. Overharvesting is the final management risk and is also a function of having a legal restriction on harvesting, which is not the case here and therefore incurs a 2% deduction.

Social Risk: This is a flat 2% for the United States.

Natural Disturbance Risk: There are three components to this risk category. Wildfire risk is a function of fire frequency, which may be reduced using specified categories of fuels treatment activity. In this case the frequency is given as 3% or a 33 year return interval. This is fairly frequent and is based on the location of the unit on the “front country” where significant fires occur down elevation to the west every 10 years or so and present a risk of expansion into the unit, as occurred in the 1978 Whitmore Fire. While shaded fuel breaks are planned and the treatments that occurred as part of this project provide tie-in points for that break, it does not yet constitute a large enough percentage on the landscape to merit a deduction in risk.

Disease or insect outbreak is given a blanket 3% risk rating. Other episodic catastrophic events are given a default value of 3%.

The total permanence risk deduction is 20% (table 11).

Table 11. Risk deductions for the Sunset unit, private lands forest management scenario.

Risks	Deduction
Financial	5.0%
Management	4.0%
Social	2.0%
Natural Dist.	9.0%
Total	20.0%

Leakage Analysis

The leakage analysis is also referred to as secondary effects analysis and is covered in section 6.2.6 for forest management project types. If the total harvest level is reduced in the project activity relative to the baseline then 20% of the difference is the reduction applied to the additionality. The value is provided on an annual and per acre basis. Table 12 shows the effect for the Sunset unit forest management scenario, which is 0.02 tonnes per acre per year.

Table 12. Secondary effects (SE) for Sunset unit, private lands forest management scenario. Units are in tonnes of C.

Project Harvested	17,268.36
Baseline Harvested	20,666.09
Gross Total Effect	3,397.74
Secondary Effect	679.55
Annual SE	-6.80
Annual SE (per acre)	-0.02

For the reforestation project type the secondary effects are specified in table 6.1 of the protocol (mobile combustion emissions for reforestation projects) and are a function of three categories of brush cover. We used the heavy category and converted the CO₂e to C to keep the units consistent at this stage of the analysis. This resulted in a one-time secondary effect of 0.12 tonnes per acre (0.3 t/h) of C that is applied the first year and carries over until there are CRTs to deduct it from.

Net Biological Additionality

The three types of deductions are shown in tables 9 and 10 as is the resulting net additionality and buffer contributions. Figures 18 and 19 illustrate the resulting marketable CRTs and the buffer pool over the project period. For the forest management project type there is a substantial salable amount of CRTs in 2025 with the first salable CRTs in 2015. The reforestation project type is surprisingly similar, on a per acre basis, with a large amount of CRTs available in 2035 and beginning in 2025.

The forest management project has two factors that make it a questionable project without modification. First, the stocking levels are just above the FIA mean. Second, the project activity plan was for harvesting between 2005 and 2015 that reduced on-site stocking. An evaluation should be made to determine whether it would be more beneficial to the landowner to delay project initiation. The requirement in the protocol to

maintain or increase on-site carbon stocks over time allows for the case where a long-term management plan decreases stocks temporarily.

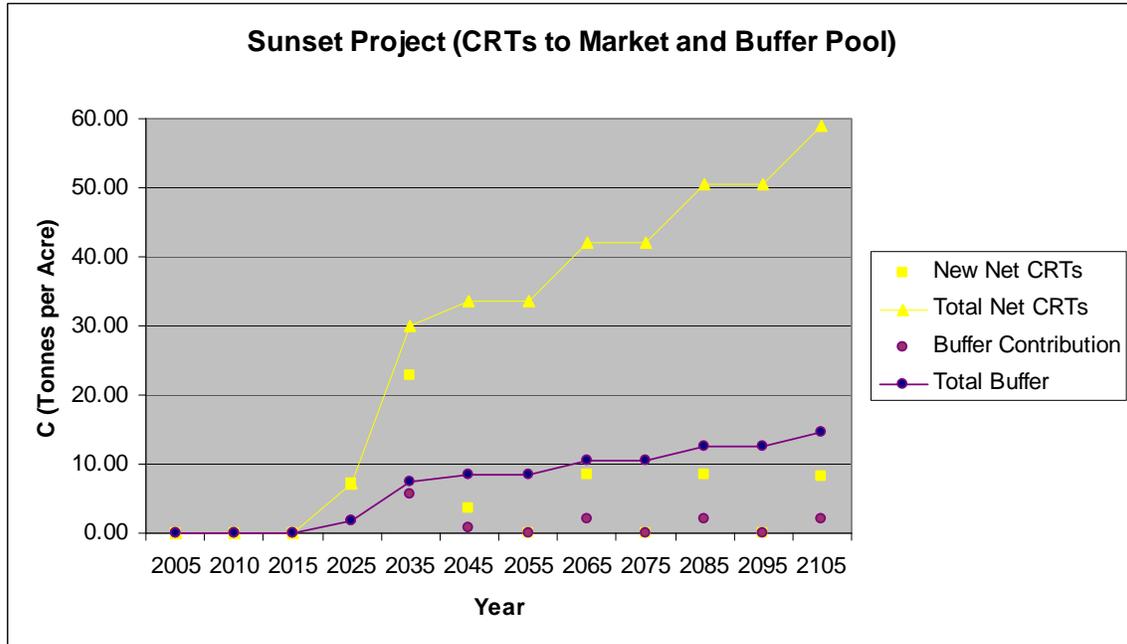


Figure 18. Net CRTs and buffer pool contributions for the Sunset unit, reforestation.

Over the 100-year life of this project the off-site long-term wood products contribution to salable gross CRTs was -3.6 tonnes per acre for the forest management type. The amount is negative because more wood products were produced in the baseline than in the project activity. There is also a reduction for this in the secondary effects calculation. The effect of the -3.6 tonne reduction from long-term wood product storage was about 1% of the total gross additionality. For the reforestation project type, projected wood products contribution to the total CRTs products was only 3.2%.

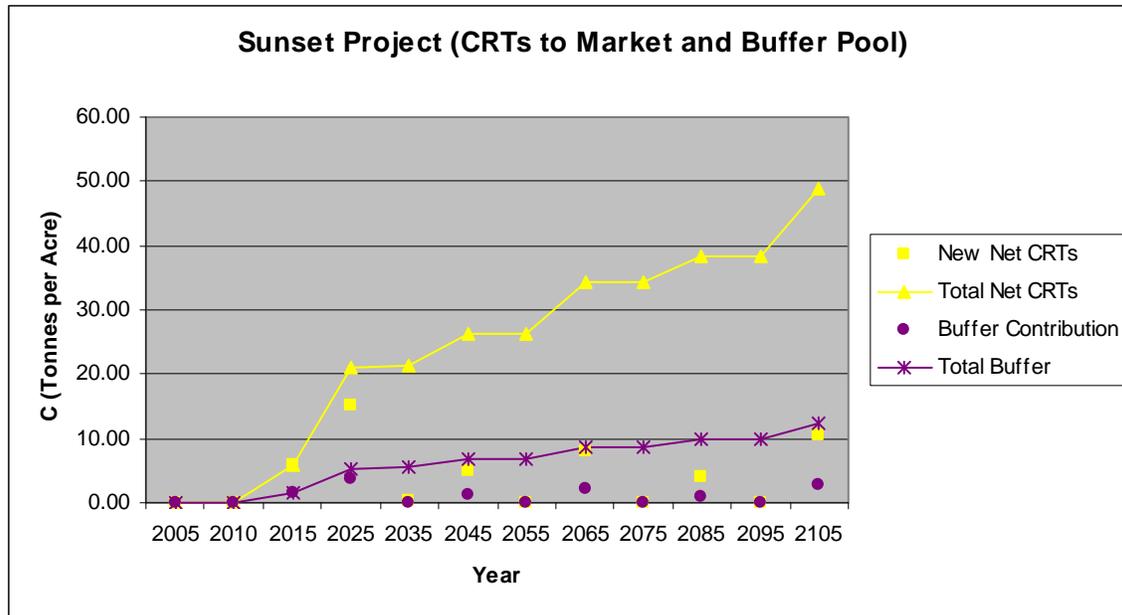


Figure 19. Net CRTs and buffer pool contributions for the Sunset unit, forest management.

Sunset Project GHG Analysis: Public Land Scenario

Projects are allowed on public lands for the first time with version 3 of the protocols. There is a requirement that the project be approved by the managing agency and that Congressional approval for carbon projects be in place for federal lands. In this case we will use LDSF as it is, a demonstration state forest. In this case the approval for a project rests with the California Department of Forestry and Fire Protection (CAL FIRE) under a management plan approved by the California Board of Forestry and Fire Protection.

The project activity and baseline for a public lands reforestation project are the same as for a private lands project. Refer to the private lands scenario for reforestation (above) for the baseline, project activity and projected additionality. There are some differences to the buffer pool contribution from the risk analysis. The financial risk is 1% instead of 5%, conversion risk is 0% rather than 2%, and overharvesting risk is 0% rather than 2%. This results in a buffer contribution that is 12% for a public land project, reduced from 20% for the private lands project (table 13). Table 14 shows the net additionality for the project.

Table 13. Risk deductions for the Sunset unit, public lands reforestation scenario.

Risks	Deduction
Financial	1.0%
Management	0.0%
Social	2.0%
Natural Dist.	9.0%
Total	12.0%

Table 14. Tonnes of carbon in the gross additionality before deductions, deductions, and net additionality; for the Sunset Unit reforestation public lands scenario.

Year	Gross Additionality						Deductions			Net Additionality			
	On-Site Additionality	Off-site Dead C Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	9.11	0.00	9.11	23.71	9.11	9.11	0.00	0.00	1.09	8.02	8.02	1.09	1.09
2035	37.56	0.00	37.56	13.85	37.56	28.45	0.00	0.00	3.41	25.04	33.05	3.41	4.51
2045	50.93	0.00	50.93	37.08	42.00	4.44	0.00	0.00	0.53	3.90	36.96	0.53	5.04
2055	37.98	4.02	42.00	4.92	42.00	0.00	0.00	0.00	0.00	0.00	36.96	0.00	5.04
2065	60.39	0.00	64.41	59.49	52.60	10.61	0.00	0.00	1.27	9.34	46.29	1.27	6.31
2075	43.76	4.83	52.60	-6.89	52.60	0.00	0.00	0.00	0.00	0.00	46.29	0.00	6.31
2085	60.79	0.00	69.63	76.52	63.24	10.64	0.00	0.00	1.28	9.36	55.65	1.28	7.59
2095	51.32	3.08	63.24	-13.28	63.24	0.00	0.00	0.00	0.00	0.00	55.65	0.00	7.59
2105	61.70	0.00	73.62	86.90	73.62	10.38	0.00	0.00	1.25	9.13	64.79	1.25	8.83

The improved forest management project type for public lands has a baseline characterization that is different from private lands. The initial inventory is to be projected for 100 years by extrapolating from historical trends and anticipating how current and future public policy will affect onsite carbon stocks. Trends for the last ten years have been for increasing stocks, which then requires that stands free of harvest for 60 years be used as a guide. Policy on state forests is to maximize timber yields, which implies operating near culmination of mean annual increment, to use an even-aged indicator. Considering that this baseline scenario will likely be near the project activity scenario, there is little or no biological additionality to be realized from a public lands scenario on LDSF. Therefore, this scenario will not be analyzed further.

McMullen Project GHG Analysis: Private Land Scenario

Like the Sunset project, this project is mostly a forest management project (tables 2 and 3). The protocols specify that the required carbon pools for a forest management project are the above- and below-ground living biomass, standing and down dead biomass (note that down dead biomass was changed to optional in the final version), and off-site dead biomass. The optional pools are shrubs and herbaceous understory, litter, and soil carbon. Only the required pools will be included in this analysis. The reforestation unit in this project also requires that shrubs and herbaceous understory be estimated. The above- and below-ground live tree biomass is required for reforestation where they exist. They are rarely present for this unit and will be tracked at future inventory periods (figures 6 and 7).

Inventory Description and Results

The inventory design and calculation methods are described in appendix I. Table 15 shows the starting carbon inventory estimate for the project along with the percent error. The protocol specifies that a reduction in CRTs occur for percent errors between 5% and 20%. Since the percent error is less than 5% there are no deductions.

Table 15. Starting carbon inventory for forest management on the McMullen Mountain project.

Attribute	Reforestation	Forest Management
No. of Plots	0	459
Mean Trees per Acre	0	141.00
Mean Trees per Hectare	0	348.27
Mean Bole Cubic Feet per Acre (ground to tip)	0	925.08
Mean Bole Cubic Meters per Hectare (ground to tip)	0	2,284.95
Mean Bole C per Acre (tonnes)	0	30.24
Mean Bole C per Hectare (tonnes)	0	74.69
Mean Bark C per Acre (tonnes)	0	13.33
Mean Bark C per Hectare (tonnes)	0	32.92
Mean Crown Branches C per Acre (tonnes)	0	6.49
Mean Crown Branches C per Hectare (tonnes)	0	16.02
Mean Tree Live Aboveground C per Acre (tonnes)	0	50.05
Mean Tree Live Aboveground C per Hectare (tonnes)	0	123.62
Mean Tree Live Belowground C per Acre (tonnes)	0	17.36
Mean Tree Live Belowground C per Hectare (tonnes)	0	42.88
Mean Tree Live C per Acre (tonnes)	0	67.41
Mean Tree Live C per Hectare (tonnes)	0	166.51
Acres	18.6	1,192.1
Hectares	7.5	482.6
Total Live Tree C (tonnes)	0	80,358.50
Total Lying Dead C (tonnes)	0.00	1.70
Total Standing Dead C (tonnes)	0.00	3.68
Total C (tonnes)	0.00	80,363.88
Standard Error C (tonnes)	na	1,748.36
Percent Error of C (%)	na	2.18%
Mean Shrub Aboveground C per Acre (tonnes)	14.60	na
Mean Shrub Aboveground C per Hectare (tonnes)	36.06	na
Mobile Combustion C per Acre (tonnes)	0.12	na
Mobile Combustion C per Hectare (tonnes)	0.29	na
Total Shrub Aboveground C (tonnes)	271.56	na
Total Reforestation C (tonnes)	273.74	na

Baseline Calculations

The baseline for the reforestation project type is the existing aboveground shrub carbon, which will be assumed to be a steady stock for the 100-year projection period. In this case it is 148.92 tonnes of C, which is 14.6 tonnes C per acre (36.1 t/h). No dead wood is assumed since the area was a brush field and no large dead wood was accumulating. No harvests were simulated. The reforestation unit is a brushfield that will undergo a slow natural succession process if left undisturbed. Given the fire frequency for the area and the high fuel load and combustion potential of this fuel type, a high-severity disturbance would be likely in a 100-year timeframe. There are no legal requirements to reforest this unit.

The baseline for forest management project types bifurcates depending on whether the starting stocks of carbon are above or below the average for the applicable assessment area (common practice), based on the FIA average. LDSF is located in the Sierra Nevada – Southern Cascades assessment area, which is 39 tonnes per acre in above- and below-ground live trees for private ownerships. Since the inventory shows 67.41 tonnes per acre in total live tree carbon, the forest management baseline shall be based on a steady flow from the FIA mean of 39 tonnes per acre. The current inventory will be the starting condition, which is 2005 in this case since that is when the project starts. The resulting baseline will have to be shown to be economically and legally feasible, which it is given that there are not significant constraints to management of the unit. The resulting average stocks over a 100-year period must be at or above the common practice figure of 39 tonnes per acre C.

If a harvest schedule uses optimization, such as a linear program, and the carbon yields are incorporated into it then the baseline may be easily modeled by changing the optimization function to match the FIA baseline figure. Otherwise, and this is the case here, modeling the harvest schedule must be done by trial and error to approach the FIA figure but end at or above it. In general, the clearfelling, whether as small group selections less than or equal to 2.5 acres (1 hectare) or clearcuts up to 20 acres (8 hectares) in size, was moved up in time and commercial thinnings with a residual basal area of 100 ft²/acre (22.9 m²/h) were used to maintain the stocking over time. These opening sizes and residual stocking meet the minimum requirements of the California forest practice regulations. Where clearcuts were implemented the minimum age requirements of the rules were met. Table 16 shows a summary of the silvicultural treatments simulated for the baseline.

Table 16. Acres of silvicultural prescriptions for the baseline simulation of the McMullen Mtn Unit for private lands forest management.

Treatment	Year									
	2005	2010	2030	2040	2050	2060	2070	2080	2090	2100
Clearfell (Group Selection and Clearcut)	0.0	273.8	221.4	0.0	224.2	0.0	228.1	0.0	186.3	0.0
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	563.2	671.7	0.0	14.1	0.0	0.0	0.0	0.0	0.0
Commercial Thin with 140 sq. ft. Residual Basal Area	0.0	285.2	0.0	0.0	265.4	0.0	404.3	0.0	742.7	0.0
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	0.0	54.6	16.1	39.6	16.1	39.6	16.1	39.6	16.1	35.2

The amount of carbon associated with the live and dead wood, on-site and off-site, for the baseline is shown in table 17. Although the landfill pool is not used for additionality calculations it is required to report it. Figures 20 and 21 show the on-site and off-site baseline estimates for the 100-year planning period. Note that the year 2010 is the only 5-

year reporting with the rest being 10-year periods. When averaging the baseline only the 10-year periods were used.

Table 17. Tonnes per acre of carbon in the baseline and project activity projections for the Sunset Unit forest management scenario.

Year	Baseline									Project					
	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	FIA Live Tree Average	On-site Live and Dead C Baseline	On-site Live and Dead C Avg Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	67.41	2.79	39.47	39.00	70.20	41.96	0.00	0.73	0.00	67.41	2.80	70.21	0.00	0.00	0.00
2010	31.16	2.72	39.47	39.00	33.89	41.96	4.79	0.73	0.77	65.24	2.75	67.98	0.76	0.76	0.12
2015	31.16	2.79	39.47	39.00	33.96	41.96	4.79	1.46	0.77	71.80	2.81	74.61	2.45	1.69	0.39
2025	43.46	3.14	39.47	39.00	46.60	41.96	7.59	1.46	1.22	69.35	3.13	72.49	2.83	0.38	0.45
2035	28.77	3.70	39.47	39.00	32.47	41.96	7.65	1.46	1.23	77.92	3.45	81.37	4.94	2.11	0.79
2045	37.60	3.69	39.47	39.00	41.29	41.96	9.20	1.46	1.48	79.16	3.71	82.87	5.27	0.33	0.84
2055	34.28	3.36	39.47	39.00	37.64	41.96	9.22	1.46	1.48	94.27	3.66	97.93	5.75	0.49	0.92
2065	44.54	3.37	39.47	39.00	47.90	41.96	11.86	1.46	1.90	97.73	3.98	101.71	6.08	0.33	0.98
2075	31.34	2.84	39.47	39.00	34.18	41.96	11.88	1.46	1.91	109.89	3.86	113.75	7.23	1.14	1.16
2085	42.12	3.29	39.47	39.00	45.41	41.96	14.40	1.46	2.31	101.95	3.79	105.74	7.49	0.26	1.20
2095	31.03	3.30	39.47	39.00	34.33	41.96	14.41	1.46	2.31	111.19	4.01	115.20	7.83	0.34	1.26
2105	42.49	3.15	39.47	39.00	45.64	41.96	14.55	1.46	2.34	109.42	4.04	113.47	7.91	0.08	1.27

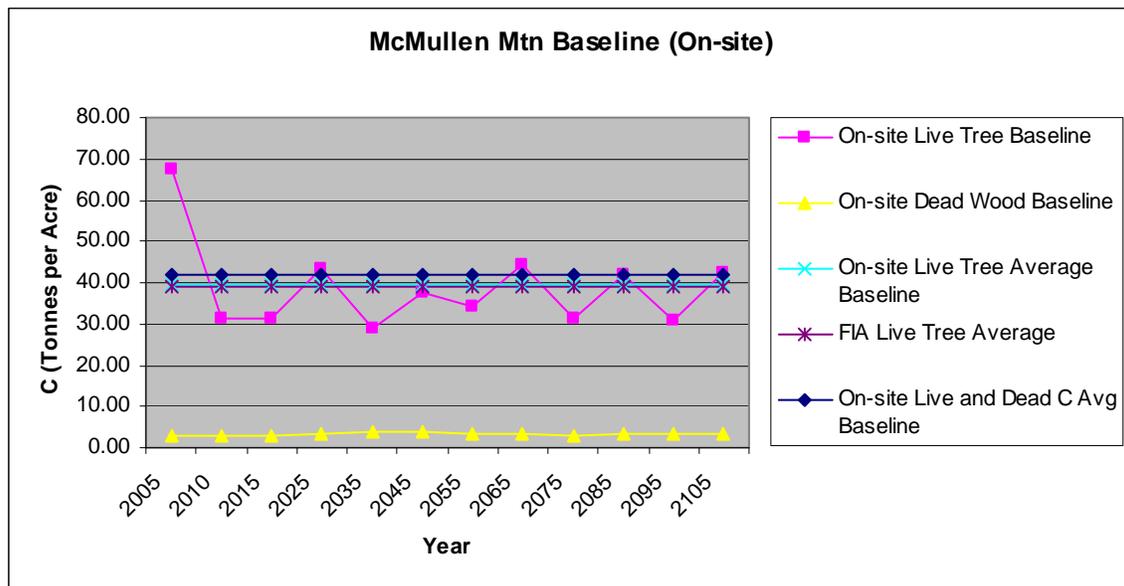


Figure 20. McMullen Mtn unit on-site baseline for private lands forest management scenario.

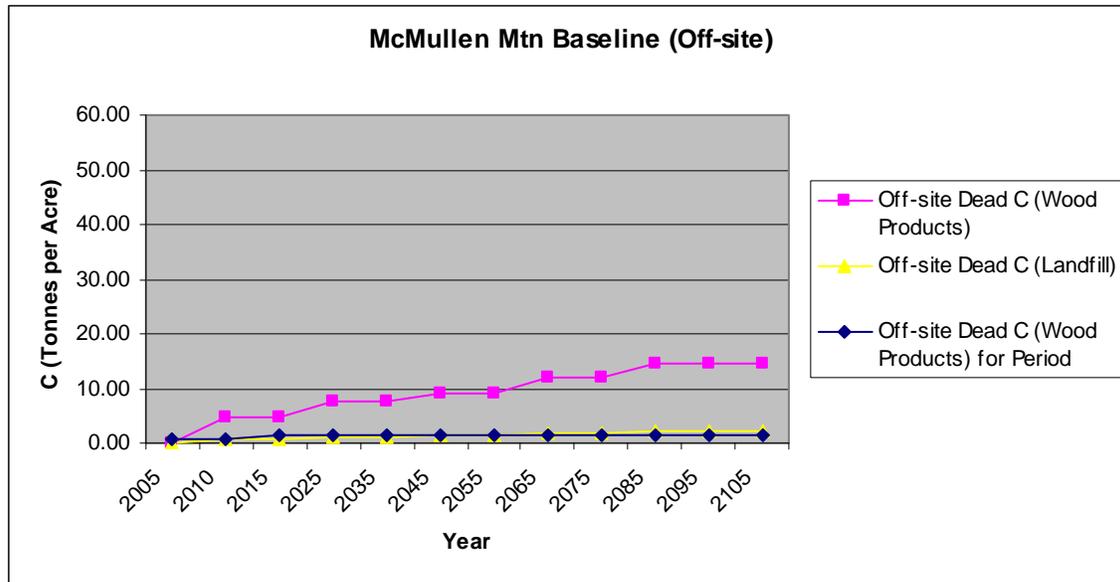


Figure 21. McMullen Mtn unit off-site baseline for private lands forest management scenario.

The results of the forest management baseline analysis were that the average on-site stocking was 39.47 tonnes of C per acre (97.5 tonnes C per hectare). Off-site wood products storage (based on 100-year storage in-use) increased over time and had an average over the period of 0.079 tonnes/acre/year C. This equated to a total of 11,257 thousand cubic feet (318,759 m³) of timber over the 100-year period. Assuming six board feet per cubic foot, this equates to 67,541 MBF total or 567 board feet per acre per year over the 100-year period.

Project Activity Calculations

The project activity for the reforestation project type was modeled as a 10x10 foot spacing of 1-0 planted seedlings of a pine and fir mix, which resulted in 436 trees per acre (1,077 trees/h). Commercial thinnings from below leaving a residual basal area of 120 ft²/ac (27.5 m²/h) were simulated in 2050, 2070, and 2090. The result of the project activity was to increase on-site carbon stocks to 45.4 tonnes C per acre (112.1 t/h) after 100 years (table 18). This is a substantially reduced projection of carbon stocks relative to the Sunset reforestation unit due to the site quality, which is 55 feet (16.8 m) high at base age 50 at McMullen relative to 110 feet (33.5 m) high at Sunset. The total wood products pool (figure 22) projected over the 100-year period was 6.7 tonnes C per acre (16.5 t/h), which was 4.4 thousand cubic feet (MCF) per acre (305 m³/h).

Table 18. Tonnes per acre of carbon in the baseline and project activity projections for the McMullen Unit reforestation scenario.

Year	Baseline					Project					
	On-site Live Tree Baseline	On-site Dead Wood Baseline	On-site Live Tree Average Baseline	Off-site Dead C (Wood Products)	Off-site Dead C (Landfill)	On-site Live Tree Project Activity	On-site Dead Wood Project Activity	On-site Live and Dead C Project Activity	Off-site Dead C (Wood Products)	Off-site Dead C (Wood Products) for Period	Off-site Dead C (Landfill)
2005	14.60	0.00	14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2010	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2015	14.60	0.00	14.60	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00
2025	14.60	0.00	14.60	0.00	0.00	2.65	0.20	2.85	0.00	0.00	0.00
2035	14.60	0.00	14.60	0.00	0.00	19.20	2.50	21.70	0.00	0.00	0.00
2045	14.60	0.00	14.60	0.00	0.00	36.04	4.42	40.46	0.00	0.00	0.00
2055	14.60	0.00	14.60	0.00	0.00	29.58	4.42	34.00	2.13	2.13	0.34
2065	14.60	0.00	14.60	0.00	0.00	43.64	4.42	48.06	2.13	0.00	0.34
2075	14.60	0.00	14.60	0.00	0.00	33.93	4.42	38.36	4.64	2.50	0.74
2085	14.60	0.00	14.60	0.00	0.00	44.68	3.55	48.23	4.64	0.00	0.74
2095	14.60	0.00	14.60	0.00	0.00	37.39	2.82	40.21	6.66	2.02	1.07
2105	14.60	0.00	14.60	0.00	0.00	45.39	2.82	48.20	6.66	0.00	1.07

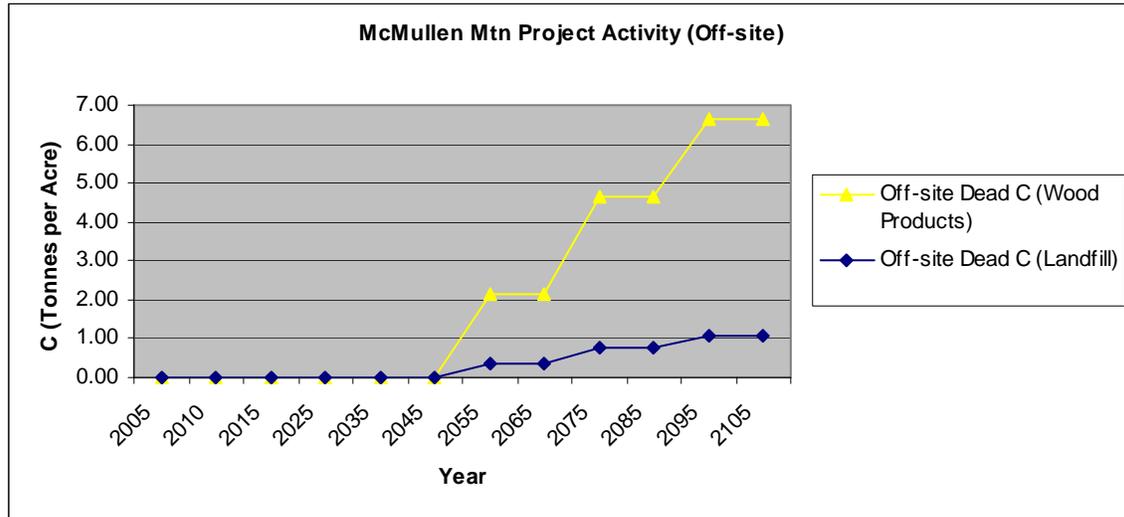


Figure 22. Reforestation project activity projections of off-site dead wood pools for McMullen reforestation project.

The project activity for the forest management project type was projected using the stand level treatments identical to the long-term harvest schedule approved by the State of California under 14 CCR 933.11(a), also known as an “option a” plan. Table 19 shows the silvicultural prescriptions. The results of the C stocking may be seen in table 17 under “Project”. Notice that there is a small near-term decrease in carbon stocks, which is a reflection of the near-term harvesting that has occurred in this unit as per the existing harvest schedule. An approximate 20-year cutting cycle is implemented on LDSF. This will have an effect on the additionality calculation that is shown below, but because the starting stocks are well above the FAI mean the effect will not be nearly as severe as was the case with the Sunset unit.

The result of the project activity projection was to increase on-site carbon stocks from an average of 67.41 tonnes/acre (166.5 tonnes/hectare) to 109.42 tonnes/acre (270.3

tonnes/hectare) at the end of the 100-year period. Off-site wood products storage grew to 7.91 tonnes/acre C (19.5 t/h), which was 46 percent less than the 14.55 tonnes/acre C (35.9 t/h) in the baseline. The harvest was projected to total 6,118 MCF (173,251 m³) of timber over the 100-year period. Figures 23 and 24 show the project activity for the on-site and off-site carbon over time.

Table 19. Acres of silvicultural prescriptions for the project activity simulation of the McMullen Mtn Unit for private lands forest management.

Treatment	Year									
	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Clearfell (Group Selection and Clearcut)	30.4	193.2	30.3	180.5	30.1	29.4	30.7	75.0	14.2	14.1
Commercial Thin with 100 sq. ft. Residual Basal Area	0.0	0.0	4.4	0.0	10.3	0.0	0.0	0.0	0.0	0.0
Commercial Thin with 140 sq. ft. Residual Basal Area	84.8	0.0	59.6	42.9	77.0	42.9	81.8	42.9	102.8	65.4
Commercial Thin with 160 sq. ft. Residual Basal Area	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.5	0.0	0.0
Single Tree Selection with 70% Basal Area Retention	42.5	0.0	81.8	0.0	14.1	0.0	0.0	0.0	0.0	0.0
Shaded Fuel Break with 50 sq. ft. Basal Area Retention	55.7	0.0	16.1	42.5	16.1	42.5	16.1	42.6	16.1	38.1

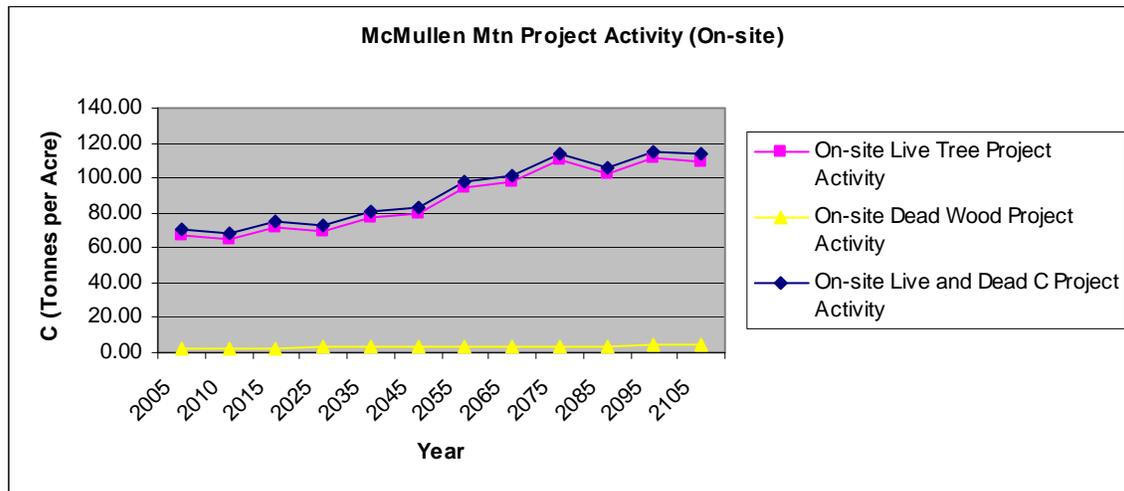


Figure 23. McMullen Mtn unit on-site project activity for the forest management project type.

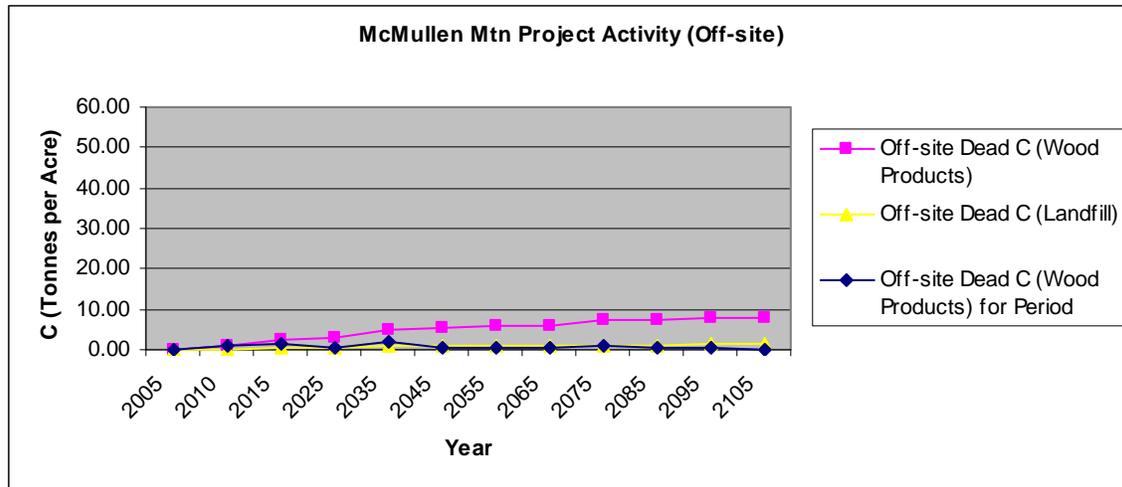


Figure 24. McMullen Mtn unit off-site project activity for the forest management project type.

Gross Biological Additionality

The difference between the project activity and baseline projections is the gross additionality, which is shown in tables 20 and 21 for the 100-year planning period and the two project types. Figures 25 and 26 show the gross additionality and the “smoothed” additionality whereby a reversal due to near-term harvests does not occur. This leads to an estimate of the decadal gross new CRTs, before any deductions for inventory precision, permanence or leakage.

Table 20. Tonnes of carbon per acre in the gross additionality before deductions, deductions, and net additionality; for the McMullen Mtn Unit reforestation scenario.

Year	Gross Additionality				Deductions					Net Additionality			
	On-Site Additionality	Off-site Dead C Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	-11.75	0.00	-11.75	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2035	7.10	0.00	7.10	4.25	7.10	7.10	0.00	0.00	1.42	5.68	5.68	1.42	1.42
2045	25.86	0.00	25.86	21.61	21.54	14.43	0.00	0.00	2.89	11.55	17.23	2.89	4.31
2055	19.40	2.13	21.54	-0.07	21.54	0.00	0.00	0.00	0.00	0.00	17.23	0.00	4.31
2065	33.46	0.00	35.60	35.67	28.40	6.86	0.00	0.00	1.37	5.49	22.72	1.37	5.68
2075	23.76	2.50	28.40	-7.27	28.40	0.00	0.00	0.00	0.00	0.00	22.72	0.00	5.68
2085	33.63	0.00	38.27	45.54	32.26	3.87	0.00	0.00	0.77	3.09	25.81	0.77	6.45
2095	25.61	2.02	32.26	-13.28	32.26	0.00	0.00	0.00	0.00	0.00	25.81	0.00	6.45
2105	33.60	0.00	40.26	53.54	40.26	8.00	0.00	0.00	1.60	6.40	32.21	1.60	8.05

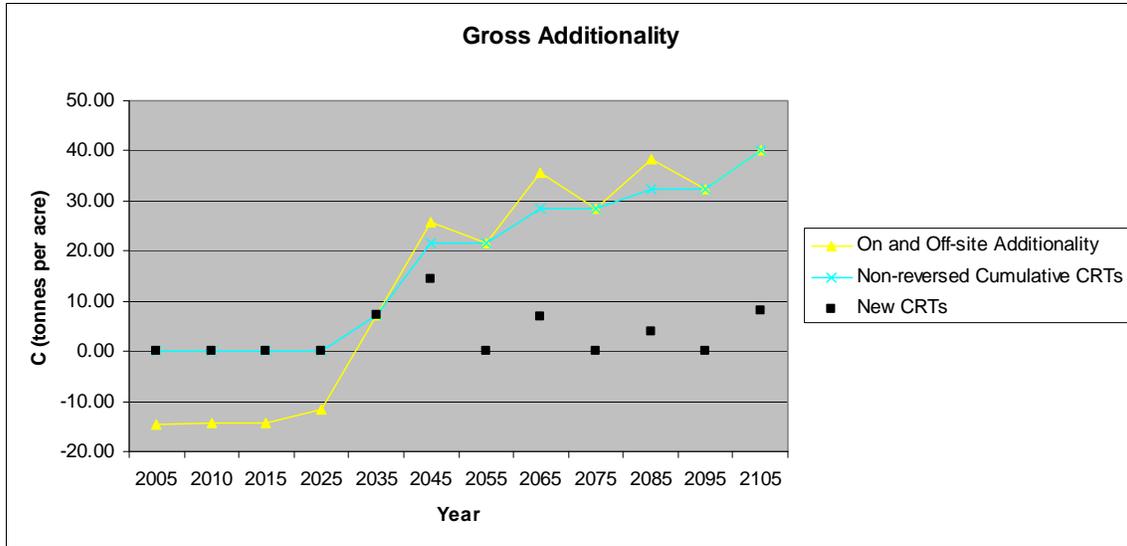


Figure 25. Reforestation, McMullen Mtn unit gross additionality and CRTs.

Table 21. Tonnes of carbon per acre in the gross additionality before deductions, deductions, and net additionality; for the McMullen Mtn Unit forest management scenario.

Year	Gross Additionality						Deductions			Net Additionality			
	On-Site Additionality	Off-site Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	28.25	-0.73	27.52	27.52	25.33	25.33	-0.24	0.00	4.94	20.15	20.15	4.94	4.94
2010	26.02	0.03	25.33	-2.20	25.33	0.00	-0.24	0.00	0.00	0.00	20.15	0.00	4.94
2015	32.65	0.24	32.19	34.38	28.99	3.67	-0.47	0.00	0.72	2.48	22.63	0.72	5.65
2025	30.53	-1.07	28.99	-5.39	28.99	0.00	-0.47	0.00	0.00	0.00	22.63	0.00	5.65
2035	39.41	0.65	38.53	43.92	38.53	9.54	-0.47	0.00	1.86	7.20	29.83	1.86	7.51
2045	40.92	-1.13	38.90	-5.02	38.90	0.37	-0.47	0.00	0.07	0.00	29.83	0.00	7.51
2055	55.97	-0.97	52.99	58.01	52.99	14.09	-0.47	0.00	2.75	10.87	40.70	2.75	10.26
2065	59.75	-1.12	55.64	-2.36	55.64	2.65	-0.47	0.00	0.52	1.66	42.36	0.52	10.78
2075	71.79	-0.31	67.38	69.74	58.17	2.52	-0.47	0.00	0.49	1.56	43.92	0.49	11.27
2085	63.78	-1.19	58.17	-11.57	58.17	0.00	-0.47	0.00	0.00	0.00	43.92	0.00	11.27
2095	73.24	-1.11	66.52	78.09	63.41	5.24	-0.47	0.00	1.02	3.75	47.67	1.02	12.29
2105	71.51	-1.38	63.41	-14.68	63.41	0.00	-0.47	0.00	0.00	0.00	47.67	0.00	12.29

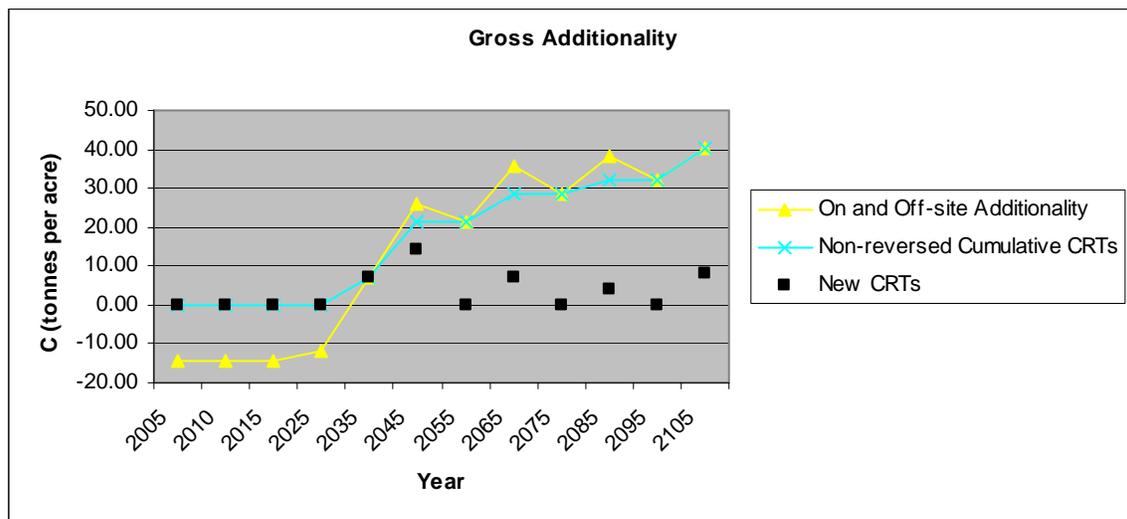


Figure 26. Forest management, McMullen Mtn unit gross additionality and CRTs.

Permanence Analysis

This is a risk analysis with the details provided in appendix D of the protocol. The analysis is identical for the reforestation and improved forest management project types.

Financial Risk: The financial risk for this private lands scenario assumes a PIA only and no conservation easement, which requires a 5% buffer contribution.

Management Risk: Management risk consists of three types of risks. Illegal removals are given a 0% risk for property in the United States. Conversion to an alternate land use is a function of whether development rights are encumbered by an easement or deed restriction, which is not the case here, incurring a 2% deduction. Overharvesting is the final management risk and is also a function of having a legal restriction on harvesting, which is not the case here and therefore incurs a 2% deduction.

Social Risk: This is a flat 2% for the United States.

Natural Disturbance Risk: There are three components to this risk category. Wildfire risk is a function of fire frequency, which may be reduced using specified categories of fuels treatment activity. In this case the frequency is given as 1% or a 100 year return interval. This is less frequent than the Sunset unit and is based on the location of the unit at a higher elevation centered on McMullen Mountain where ridgetop firelines would increase the probability of halting fire spread. While shaded fuel breaks are planned and the treatments that occurred as part of this project provide tie-in points for that break, it does not yet constitute a large enough percentage on the landscape to merit a deduction in risk.

Disease or insect outbreak is given a blanket 3% risk rating. Other episodic catastrophic events are given a default value of 3%.

The total permanence risk deduction is 18% (table 22).

Table 22. Risk deductions for the McMullen Mtn unit, private lands forest management scenario.

Risks	Deduction
Financial	5.0%
Management	4.0%
Social	2.0%
Natural Dist.	7.0%
Total	18.0%

Leakage Analysis

The leakage analysis is also referred to as secondary effects analysis and is covered in section 6.2.6 for forest management project types. If the total harvest level is reduced in the project activity relative to the baseline then 20% of the difference is the reduction applied to the additionality. The value is provided on an annual and per acre basis. Table 23 shows the effect for the McMullen Mtn unit forest management scenario, which is 0.05 tonnes per acre per year.

Table 23. Secondary effects (SE) for McMullen Mtn unit, private lands forest management scenario. Units are in tonnes of C.

Project Harvested	33,582.21
Baseline Harvested	61,786.94
Gross Total Effect	28,204.73
Secondary Effect	5,640.95
Annual SE	-56.41
Annual SE (per acre)	-0.05

For the reforestation project type the secondary effects are specified in table 6.1 of the protocol (mobile combustion emissions for reforestation projects) and are a function of three categories of brush cover. We used the heavy category and converted the CO₂e to C to keep the units consistent at this stage of the analysis. This resulted in a one-time secondary effect of 0.12 tonnes per acre (0.3 t/h) of C that is applied the first year and carries over until there are CRTs to deduct it from.

Net Biological Additionality

The three types of deductions are shown in tables 20 and 21 as is the resulting net additionality and buffer contributions. Figures 27 and 28 illustrate the resulting marketable CRTs and the buffer pool over the project period. For the forest management project type there is a substantial salable amount of CRTs immediately with substantial amounts also in 2035 and 2065. The reforestation project type is similar to the Sunset reforestation project at a lower level and a decade later, on a per acre basis, with a large amount of CRTs available in 2045 and beginning in 2035.

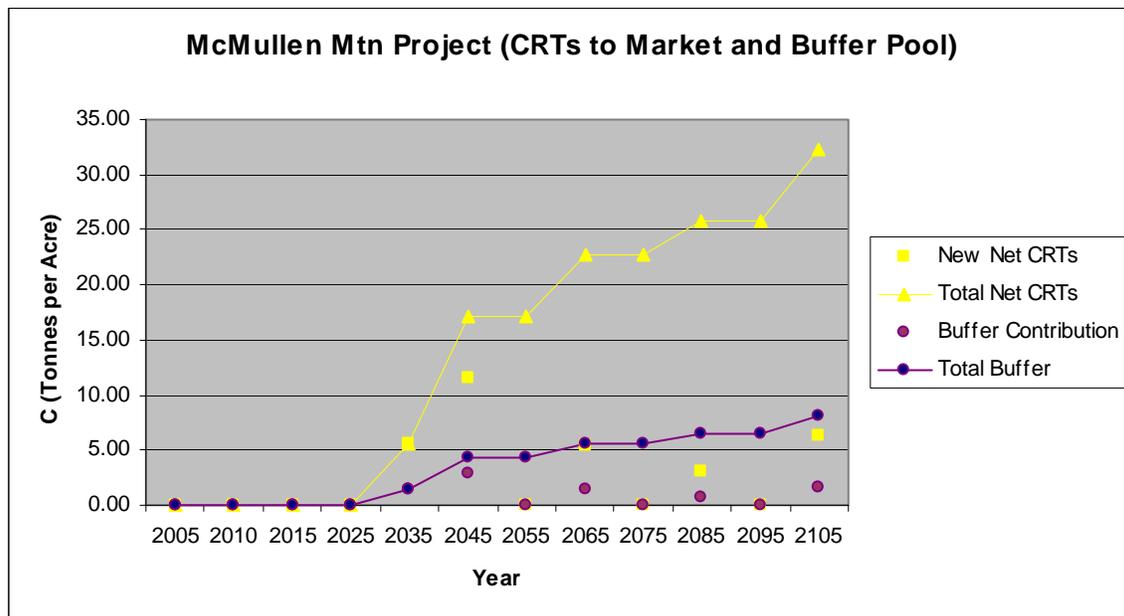


Figure 27. Net CRTs and buffer pool contributions for the McMullen Mtn unit, reforestation.

Over the 100-year life of this project the off-site long-term wood products contribution to salable gross CRTs was -8.1 tonnes per acre for the forest management type. The amount is negative because more wood products were produced in the baseline than in the

project activity. There is also a reduction for this in the secondary effects calculation. The effect of the -8.1 tonne reduction from long-term wood product storage was about 13% of the total gross additionality. For the reforestation project type, projected wood products contribution to the total CRTs products was only 4.5%.

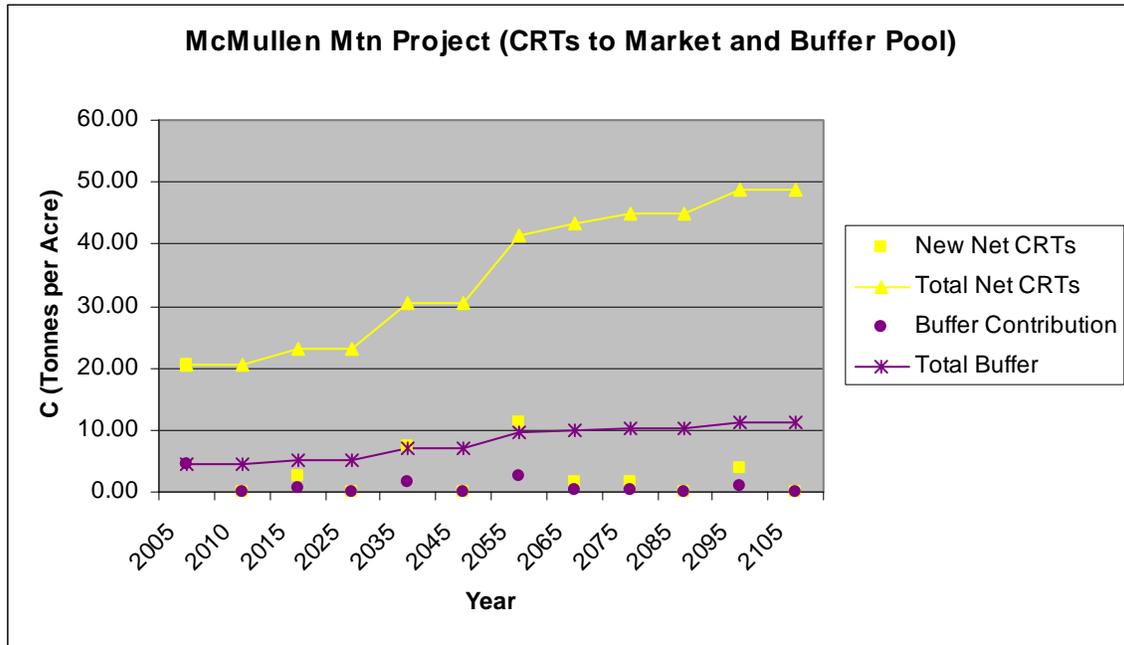


Figure 28. Net CRTs and buffer pool contributions for the McMullen Mtn unit, forest management.

McMullen Project GHG Analysis: Public Land Scenario

Projects are allowed on public lands for the first time with version 3 of the protocols. There is a requirement that the project be approved by the managing agency and that Congressional approval for carbon projects be in place for federal lands. In this case we will use LDSF as it is, a demonstration state forest. In this case the approval for a project rests with the California Department of Forestry and Fire Protection (CAL FIRE) under a management plan approved by the California Board of Forestry and Fire Protection.

The project activity and baseline for a public lands reforestation project are the same as for a private lands project. Refer to the private lands scenario for reforestation (above) for the baseline, project activity and projected additionality. There are some differences to the buffer pool contribution from the risk analysis. The financial risk is 1% instead of 5%, conversion risk is 0% rather than 2%, and overharvesting risk is 0% rather than 2%. This results in a buffer contribution that is 10% for a public land project, reduced from 18% for the private lands project (table 24). Table 25 shows the net additionality for the project.

Table 24. Risk deductions for the McMullen Mtn unit, public lands reforestation scenario.

Risks	Deduction
Financial	1.0%
Management	0.0%
Social	2.0%
Natural Dist.	7.0%
Total	10.0%

Table 25. Tonnes of carbon in the gross additionality before deductions, deductions, and net additionality; for the McMullen Mtn Unit reforestation public lands scenario.

Year	Gross Additionality						Deductions			Net Additionality			
	On-Site Additionality	Off-site Dead C Additionality (Wood Products)	On and Off-site Additionality	Total Marginal Additionality	Non-reversed Cumulative CRTs	New CRTs	Secondary Effects	Inventory Confidence Deduction	Buffer Pool Deduction	New Net CRTs	Total Net CRTs	Buffer Contribution	Total Buffer
2005	-14.60	0.00	-14.60	-14.60	0.00	0.00	-0.12	0.00	0.00	0.00	0.00	0.00	0.00
2010	-14.40	0.00	-14.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2015	-14.40	0.00	-14.40	-14.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2025	-11.75	0.00	-11.75	2.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2035	7.10	0.00	7.10	4.25	7.10	7.10	0.00	0.00	0.71	6.39	6.39	0.71	0.71
2045	25.86	0.00	25.86	21.61	21.54	14.43	0.00	0.00	1.44	12.99	19.38	1.44	2.15
2055	19.40	2.13	21.54	-0.07	21.54	0.00	0.00	0.00	0.00	0.00	19.38	0.00	2.15
2065	33.46	0.00	35.60	35.67	28.40	6.86	0.00	0.00	0.69	6.17	25.56	0.69	2.84
2075	23.76	2.50	28.40	-7.27	28.40	0.00	0.00	0.00	0.00	0.00	25.56	0.00	2.84
2085	33.63	0.00	38.27	45.54	32.26	3.87	0.00	0.00	0.39	3.48	29.04	0.39	3.23
2095	25.61	2.02	32.26	-13.28	32.26	0.00	0.00	0.00	0.00	0.00	29.04	0.00	3.23
2105	33.60	0.00	40.26	53.54	40.26	8.00	0.00	0.00	0.80	7.20	36.23	0.80	4.03

The improved forest management project type for public lands has a baseline characterization that is different from private lands. The initial inventory is to be projected for 100 years by extrapolating from historical trends and anticipating how current and future public policy will affect onsite carbon stocks. Trends for the last ten years have been for increasing stocks, which then requires that stands free of harvest for 60 years be used as a guide. Policy on state forests is to maximize timber yields, which implies operating near culmination of mean annual increment, to use an even-aged indicator. Considering that this baseline scenario will likely be near the project activity scenario, there is little or no biological additionality to be realized from a public lands scenario on LDSF. Therefore, this scenario will not be analyzed further.

Economic Analysis

This section provides costs and revenue estimates, provides a spreadsheet tool to evaluate the economics of the reforestation and improved forest management project types using these projects as examples, and shows the economic feasibility of these projects. The CVal spreadsheet program (Bilek et al. 2009), originally developed for Chicago Climate Exchange (CCX) forestry protocols, was adapted for the CAR forestry protocols, version 3.

Costs of the Projects

Project costs for the two project areas, forest management and reforestation are shown in tables 26-29. These tables are taken directly from the modified CVal spreadsheet (Bilek et al. 2009). Many of these costs will vary substantially from project to project and will

depend on if an acceptable inventory already exists, the size of the project and whether aggregating with other landowners. The reforestation projects assume a \$600 per acre site preparation, planting and competing vegetation cost. The verification costs were set at a fixed cost of \$1,000.00 plus a variable cost of \$5.00 per acre. The periodic inventory costs for the smaller reforestation projects were set at a fixed cost of \$500.00 plus a variable cost of \$50 per acre. The larger improved forest management period inventories were set at a \$1,000.00 fixed cost and \$20 per acre.

Table 26. Sunset improved forest management costs.

Tract size	426 acres	Initial inventory cost	\$ - per tract
Year 1 carbon sequestration rate	- tonnes CO ₂ e/ac/yr	Management plan cost	\$ - per tract
Sequestration rate is...	Variable <i>Fill in rates in table below.</i>	Periodic verification cost	\$ 3,129 per tract
Carbon reserve pool factor	10%	Other up-front costs	\$ 1,000 per tract
Initial carbon price	\$ 9.00 per tonne CO ₂ e	Contract year (Year that up-front costs occur)	1 (counter year)
Carbon price is...	Constant	Periodic inventory cost	\$ 9,516 per tract
Aggregator's fee	0%	End of project costs	\$ 1,000 per tract
Verification fee	\$ 0.25 per tonne CO ₂ e	Hurdle rate	5.0%
Annual reporting cost	\$ 300.00 per tract	Finance rate	5.0%
Trading fee	\$ 0.20 per tonne CO ₂ e	Count pre-contract carbon?	No
Other annual costs	\$ 1.00 per acre	End-of-project year	2104
Up-front costs sensitivity factor	0%		
Annual costs sensitivity factor	0%	Total up-front costs	\$ 1,000 per tract
End-of-project costs sensitivity factor	0%	Total end-of-project costs	\$ 1,000 per tract

Table 27. McMullen improved forest management costs.

Tract size	1,192 acres	Initial inventory cost	\$ -	per tract
Year 1 carbon sequestration rate	- tonnes CO ₂ e/ac/yr	Management plan cost	\$ -	per tract
Sequestration rate is...	Variable <i>Fill in rates in table below.</i>	Periodic verification cost	\$ 6,961	per tract
Carbon reserve pool factor	10%	Other up-front costs	\$ 1,000	per tract
Initial carbon price	\$ 9.00 per tonne CO ₂ e	Contract year (Year that up-front costs occur)	1	(counter year)
Carbon price is...	Constant	Periodic inventory cost	\$ 24,842	per tract
Aggregator's fee	0%	End of project costs	\$ 1,000	per tract
Verification fee	\$ 0.25 per tonne CO ₂ e	Hurdle rate	5.0%	
Annual reporting cost	\$ 300.00 per tract	Finance rate	5.0%	
Trading fee	\$ 0.20 per tonne CO ₂ e	Count pre-contract carbon?	No	
Other annual costs	\$ 1.00 per acre	End-of-project year	2104	
Up-front costs sensitivity factor	0%			
Annual costs sensitivity factor	0%	Total up-front costs	\$ 1,000	per tract
End-of-project costs sensitivity factor	0%	Total end-of-project costs	\$ 1,000	per tract

Table 28. Sunset reforestation costs.

Tract size	10 acres	Initial inventory cost	\$ -	per tract
Year 1 carbon sequestration rate	- tonnes CO ₂ e/ac/yr	Management plan cost	\$ -	per tract
Sequestration rate is...	Variable <i>Fill in rates in table below.</i>	Periodic verification cost	\$ 1,051	per tract
Carbon reserve pool factor	10%	Other up-front costs	\$ 7,120	per tract
Initial carbon price	\$ 9.00 per tonne CO ₂ e	Contract year (Year that up-front costs occur)	1	(counter year)
Carbon price is...	Constant	Periodic inventory cost	\$ 1,010	per tract
Aggregator's fee	0%	End of project costs	\$ 1,000	per tract
Verification fee	\$ 0.25 per tonne CO ₂ e	Hurdle rate	5.0%	
Annual reporting cost	\$ 300.00 per tract	Finance rate	5.0%	
Trading fee	\$ 0.20 per tonne CO ₂ e	Count pre-contract carbon?	No	
Other annual costs	\$ 1.00 per acre	End-of-project year	2104	
Up-front costs sensitivity factor	0%			
Annual costs sensitivity factor	0%	Total up-front costs	\$ 7,120	per tract
End-of-project costs sensitivity factor	0%	Total end-of-project costs	\$ 1,000	per tract

Table 29. McMullen Mountain reforestation costs.

Tract size	19 acres	Initial inventory cost	\$ -	per tract
Year 1 carbon sequestration rate	- tonnes CO ₂ e/ac/yr	Management plan cost	\$ -	per tract
Sequestration rate is...	Variable <i>Fill in rates in table below.</i>	Periodic verification cost	\$ 1,093	per tract
Carbon reserve pool factor	10%	Other up-front costs	\$ 12,160	per tract
Initial carbon price	\$ 9.00 per tonne CO ₂ e	Contract year (Year that up-front costs occur)	1	(counter year)
Carbon price is...	Constant	Periodic inventory cost	\$ 1,430	per tract
Aggregator's fee	0%	End of project costs	\$ 1,000	per tract
Verification fee	\$ 0.25 per tonne CO ₂ e	Hurdle rate	5.0%	
Annual reporting cost	\$ 300.00 per tract	Finance rate	5.0%	
Trading fee	\$ 0.20 per tonne CO ₂ e	Count pre-contract carbon?	No	
Other annual costs	\$ 1.00 per acre	End-of-project year	2104	
Up-front costs sensitivity factor	0%			
Annual costs sensitivity factor	0%	Total up-front costs	\$ 12,160	per tract
End-of-project costs sensitivity factor	0%	Total end-of-project costs	\$ 1,000	per tract

Carbon and Timber Revenues

This analysis only considers the carbon revenues in the financial analysis, timber revenues may be added in separately. In fact, if timber revenues are forgone or delay there may be significant costs and therefore reductions in net present value. Two CO₂e prices were considered, the current prevailing over the counter price for voluntary market CAR project CRTs of \$9.00/tonne and a realistic long-term compliance CRT price of \$20.00/tonne. There is an assumed 10% holdback in addition to required buffer pools since this is common practice in OTC voluntary transactions.

Direct Benefits of the Four Scenarios

A 5% hurdle rate is assumed. Neither of the reforestation projects produced a positive NPV at \$9.00/t or at \$20.00/t. The Sunset improved forest management project, at \$9.00/t, produced a positive NPV of \$92,584, which is \$217.44/acre (\$537.07/h). At \$20.00/t, the Sunset forest management project produced a NPV of \$249,125 or \$585.07/acre (1,445.12/h). The McMullen Mountain improved forest management project had initial carbon stocks well above the FIA mean so there were immediate CRTs produced. This resulted in a NPV, at \$9.00/t, of \$773,385, which is \$648.76/acre (\$1,602.44/h). At the \$20.00/t price the NPV was \$1,869,167 or \$1,567.96/acre (\$3,872.86/h).

Sensitivity Analysis

The carbon price was varied to determine the break even point for the four project scenarios. The Sunset reforestation project required a price of \$48.57/t CO₂e to break

even. The McMullen Mountain reforestation project required a price of \$99.19/t CO₂e to break even. The difference in price is due to the lower site productivity of the later unit, which results in lower and later CRTs.

The break even CRT price for the Sunset improved forest management project was \$2.50/t. The McMullen Mountain forest management project had a break even price of \$1.24/t. The improved forest management projects were much more lucrative due to not having the large up front costs the reforestation entails and because CRTs may be realized earlier. Where timber is a competing income stream to carbon the timber values associated with the carbon project activity versus the baseline scenario could be computed to determine the optimum mix of commodities. This could be analyzed for different costs and revenue points.

Fuels Treatment Analysis

The impact of fuels treatments on the carbon accounting of the treated and surrounding stands is an area of current research and policy debate. Version 3 of the CAR protocols acknowledges the utility of fuel treatments on the landscape by providing a risk reduction for different treatment categories of none, low, medium and high, which are not quantitatively defined. These can reduce the annual probability of the fire multiplier by 0%, 17.4%, 33.6%, and 50% respectively. For example, a return interval of 10 years would produce an annual probability of fire of 10%. With no treatments this would remain a 10% deduction. A high level of treatments would reduce it by one half so that a 5% risk deduction would apply.

This section simulates the planned implementation of a shaded fuel break that ties in with the treatments implemented as part of this project (figure 4). The fire break runs along a ridge from the Sunset unit generally east to the top of McMullen Mountain and then down to treatment areas to the northeast (figure 1). Pre and post fire simulations are performed and assumptions are made about the benefits of risk reduction for neighboring stands. The carbon benefits are then estimated.

Fuel Treatments

The proposed shaded fuel break on LDSF will be 300 feet in width, retain a post-harvest basal area of 50 ft²/acre (11.5 m²/h), and reduce ground and ladder fuels. Table 30 shows the stands that are part of the shaded fuel break, which total 75 acres (30 hectares). Pre and post treatment conditions are shown. These are in addition to the units treated as part of the reforestation and improved forest management. An example depiction of a treatment is shown in figure 29. This shows the thinning of the trees, but the ground fuels are also reduced by either piling and burning or chipping and hauling to a biomass plant. We are assuming here that the understory is piled and burned because current market conditions do not allow for hauling from LDSF to a biomass facility. The pre and post harvest condition was matched to the most appropriate fuel model (table 30) for fire behavior simulation.

Table 30. Summary of stands in the proposed shaded fuel break.

Stand	Acres	WHR Class	Pre-Treatment			Fuel model (Photo series)	Fuel model (FB-Model 2005)	Fuel Load, Biomass (tons/ac)	Post-Treatment			Fuel model (FB-Model 2005)	Fuel Load, Biomass (tonnes/ac)
			Trees per Acre	Basal Area (sq. ft./ac.)	Quadratic Mean Diameter (inches)				Trees per Acre	Basal Area (sq. ft./ac.)	Fuel model (Photo series)		
STAND_105_BREAK	13.9	WFR4D	117.7	236	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	36.1	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_106	2.2	WFR4D	179.5	177	14.7	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	43.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_118_BREAK	2.7	WFR4D	108	216	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	22.7	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_123_BREAK	1.8	WFR4M	44.7	65	16.4	PNW-95/1-TF-4-PC True Fir, size class 4, partial cut	TL01	17.6	28.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_155	5.5	WFR4D	117.7	236.01	19.2	PNW-95/2-TF-4-PC True Fir, size class 4, partial cut	TL04	24.7	22.9	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_156	14.1	KMC4M	141.1	127.2	12.9	PNW-95/3-MC-4-PC Mixed Conifer, size class 4, partial cut	TL01	28.6	47.9	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_158	5.9	KMC4M	67.4	94.2	16	PNW-95/3-MC-4-PC Mixed Conifer, size class 4, partial cut	TL01	28.6	32.2	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_164_BREAK	1.8	KMC4D	159.9	271.7	17.7	PNW-95/4-MC-4-PC Mixed Conifer, size class 4, partial cut	TL07	38.2	26.7	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
STAND_390_BREAK	7.8	KMC4D	111.7	186.6	17.5	PNW-95/4-MC-4-PC Mixed Conifer, size class 4, partial cut	TL07	38.2	27.3	50	PNW-95/2-TF-4-RC True Fir, Size Class 4, Regeneration Cut	TL01	6.9
S129_BREAK	19.1	KMC2P	314.57	50.62	5.4	PNW-105/1-PP-1 Ponderosa pine, size class 1, natural	TL-08	10	116.66	50	PNW-52/4-PP-1-TH Ponderosa pine, size class 1, thinned, assume pile and burn slash	TL07	2.7

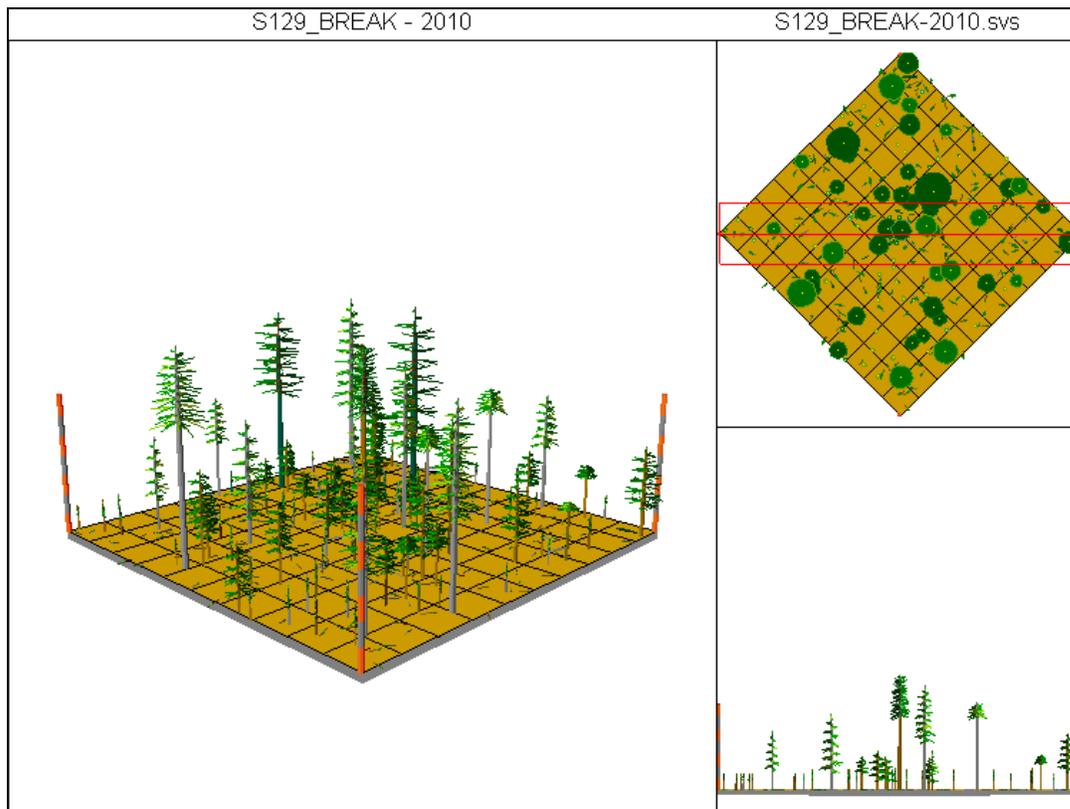


Figure 29. Stand 129 shaded fuel break in 2010 showing removal of small trees.

Fire Simulations in Treated Stands

Fire behavior was simulated using Fuels Management Analyst Plus version 3 (FMA 2009). The FVS tree list files for each of the stands was input directly into FMA. Weather conditions for the categories of moderate, high and extreme were derived from local RAWS stations using Fire Family Plus version 4 (Bradshaw and Brittain 2008) from the ten year period 1999-2008. The fire weather categories for LDSF are shown in table 31. Burning index was used as the parameter to determine the fire weather categories. Moderate weather has a 75% climatological probability, high severity weather a 7% probability and extreme a 3% probability. This probability covers the fire season, which is defined as May 1 to October 31.

Table 31. Fire weather for LDSF.

		Condition Category		
		Moderate	High	Extreme
Fuel Moisture (percent)	1-hour dead	4.86	3.31	2.86
	10-hour dead	6.12	4.31	3.81
	100-hour dead	10.08	7.56	7.45
	1000-hour dead	12.11	9.31	8.85
	Herbaceous live	11.56	3.49	2.86
	Woody live	81.77	72.19	70.41
Wind (mph)	20-foot wind speed	4	5.84	6.83

Figure 31 shows a profile of the crown density of a stand. FMA is sensitive to ground and canopy fuel interactions, which is ideal for analyzing the effects of fuel treatments. Tables 32-34 show the results of the modeling for the moderate, high and extreme weather conditions. In general both treated and untreated stands were surface fires with little or no crown scorching or tree mortality, the exception being the small tree stand 129. The primary benefit of the treatments was to decrease the rate of spread in many of the stands. Given that the 300 foot width is 4.5 chains (one chain is 66 feet) and the maximum fire spread is reduced from 3.2 to 1.7 chains per hour under extreme weather conditions, this allows more than two hours for resources to respond or hold the line at the fuel break. In all cases the flame lengths are below 4 feet, which is a rule of thumb for where hand crews must transition to dozers due to heat intensity. Therefore, all resources may be brought to bear at this location under all the weather scenarios.

The weather scenarios are likely conservative in that the winds may be higher than modeled because of the ridge-top location. Based on this modeling a shaded fuel break would not be necessary, it would not be beneficial to separate tree crowns because the ground fire would not reach the crowns even under extreme weather conditions. If this could be reliably determined then an understory biomass harvest would be beneficial, which would retain most of the carbon on site. Since a shaded fuel break can allow more light and wind to the ground, creating hotter and drier understory conditions, all of these factors should be considered in total.

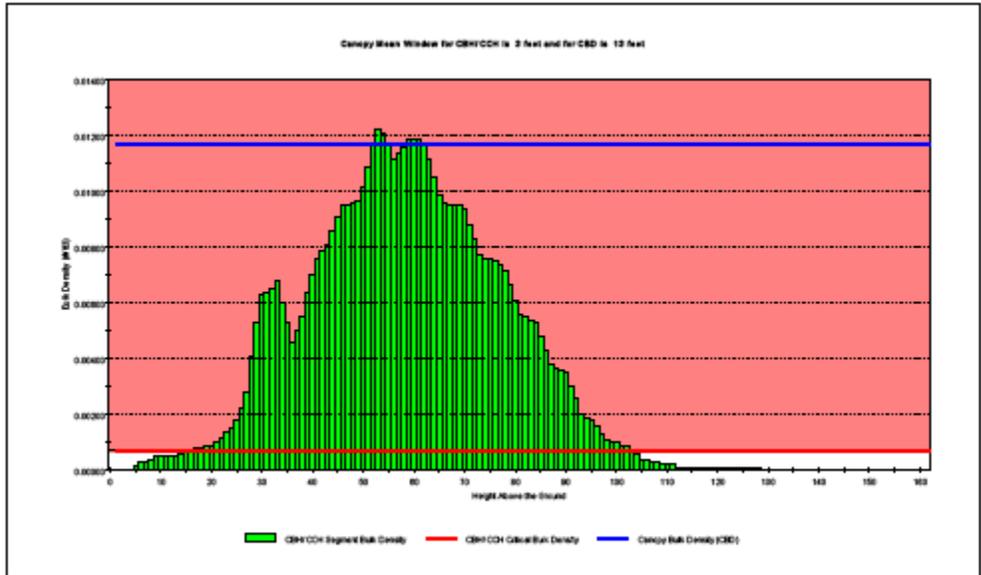


Figure 30. Canopy density for stand 105, used for fire modeling.

Table 32. Fire modeling results for moderate weather conditions.

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	0.8	0.3	0.7	0.3	65	68	0.10	0.10	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.10	0.10	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.11	0.11	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	0.8	0.3	0.7	0.3	67	67	0.11	0.12	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.3	0.3	0.3	0.3	67	67	0.10	0.10	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.2	0.3	0.9	0.3	67	67	0.11	0.10	10.8	10.8	0.0	0.0
STAND_390_BREAK	Surface	Surface	1.2	0.3	0.9	0.3	67	67	0.10	0.10	11.7	11.7	0.0	0.0
S129_BREAK	Surface	Surface	1.9	1.2	1.7	0.9	67	67	0.10	0.08	29.8	25.5	25.5	0.1

Table 33. Fire modeling results for high weather conditions.

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	1.0	0.4	1.1	0.4	81	84	0.15	0.15	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.15	0.15	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.16	0.16	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.15	0.15	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	1.0	0.4	1.1	0.4	82	82	0.16	0.16	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.14	0.14	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.4	0.4	0.4	0.4	82	82	0.15	0.15	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.6	0.4	1.5	0.4	82	82	0.16	0.16	10.8	10.8	0.0	0.0
STAND_390_BREAK	Surface	Surface	1.6	0.4	1.5	0.4	82	82	0.16	0.16	11.7	11.7	0.0	0.0
S129_BREAK	Surface	Surface	2.5	1.6	2.7	1.5	82	82	0.14	0.12	32.9	35.2	39.5	29.7

Table 34. Fire modeling results for extreme weather conditions.

Stand	Fire Type		Flame Length (feet)		Rate of Spread (ch/hr)		Probability of Ignition (%)		Spotting Distance from Torching Tree (mi)		Percent Mortality		Average Crown Scorch (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
STAND_105_BREAK	Surface	Surface	1.1	0.5	1.3	0.5	86	89	0.18	0.17	16.1	16.1	0.0	0.0
STAND_106	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.17	0.17	17.9	17.9	0.0	0.0
STAND_118_BREAK	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.19	0.19	11.0	11.0	0.0	0.0
STAND_123_BREAK	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.18	0.18	11.2	11.2	0.0	0.0
STAND_155	Surface	Surface	1.1	0.5	1.3	0.5	88	88	0.19	0.19	12.5	12.5	0.0	0.0
STAND_156	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.17	0.17	18.1	18.1	0.0	0.0
STAND_158	Surface	Surface	0.5	0.5	0.5	0.5	88	88	0.18	0.18	16.7	16.7	0.0	0.0
STAND_164_BREAK	Surface	Surface	1.7	0.5	1.7	0.5	88	88	0.18	0.18	10.8	10.8	0.1	0.0
STAND_390_BREAK	Surface	Surface	1.7	0.5	1.7	0.5	88	88	0.18	0.18	10.8	10.8	0.0	0.0
ST129_BREAK	Surface	Surface	2.7	1.7	3.2	1.7	88	88	0.17	0.14	36.0	36.2	43.6	31.9

Carbon and Fire Risk Tradeoff Analysis

The carbon reduction from the shaded fuel break treatments reduces stocks from approximately 48.6 tonnes of live (above and below ground) carbon per acre (120.0 t/h) to 20.4 t/a (49.4 t/h) for a reduction of 28.2 t/a (69.7 t/h) total. In five years this recovers to 24.7 t/a (61.0 t/h). Considering just the treated acres and based on the fire modeling, there was not a net benefit to the thinning from a carbon standpoint. Significant carbon was removed and the site occupancy will be maintained over time at this lower level. Some of this will be recovered in long-term wood products storage and if prices for biomass improves over time there will be higher utilization of the understory thinning material. The pre versus post treatment fire behavior modeling does not change significantly in this case.

Since the proposed fuel break divides the two project areas in half approximately, consider the fuel break as protecting one half of the total carbon stocks over a 100-year project period. What would the expected average value be given these assumptions? Equation 1 provides a way to quantify the estimate of the value of the shaded fuel break where it is assumed to protect one half of the project carbon.

$$CVS = LTL + \sum_t (PF_t \times PC_t) \times FREQ_t \times (EL_t \times EP_t + HL_t \times HP_t + ML_t \times MP_t) + RECAP \quad (1)$$

Where CVS = carbon value saved by implementing project,

LTL = long-term loss from fuel break treatment,

PF = protection factor (what proportion of project is protected),

PC = project carbon on site,

FREQ = average long-term fire frequency as an annual probability,

EL = extreme weather loss of carbon as a proportion,

EP = extreme weather probability (annual),

HL = high severity weather loss of carbon as a proportion,

HP = high severity weather probability (annual),

ML = moderate weather loss of carbon as a proportion,

MP = moderate weather probability (annual),

RECAP = recapture of site given incident (in carbon), and

t = time, which is 100 years in this case but may be in 5 or 10-year increments.

The following is an example of using equation (1). Several examples are shown in table 35 that illustrate that *CVS* may be positive or negative depending on the parameters and assumptions. *RECAP* may be complex in that reforestation or natural succession would have to be modeled. Alternatively, a persistent brush field may occur, especially on non-industrial private lands where there is no legal requirement and it is often common not to reforest after a catastrophic fire. In this example we assume that is the case and *RECAP*=0.

Table 35. Example calculations of carbon tonnes protected by shaded fuel break under different assumptions.

Parameter	Example			
	Expected	More Severe Fire outside Fuel Break	Increased Frequency	Less Protection
<i>LTL</i>	-2,109.4	-2,109.4	-2,109.4	-2,109.4
<i>PF</i>	0.50	0.50	0.50	0.20
<i>PC</i>	98,616.9	98,616.9	98,616.9	98,616.9
<i>FREQ</i>	0.03	0.03	0.10	0.03
<i>EL</i>	0.30	0.60	0.30	0.30
<i>EP</i>	0.03	0.03	0.03	0.03
<i>HL</i>	0.20	0.40	0.20	0.20
<i>HP</i>	0.07	0.07	0.07	0.07
<i>ML</i>	0.10	0.20	0.10	0.10
<i>MP</i>	0.75	0.75	0.75	0.75
<i>RECAP</i>	0.0	0.0	0.0	0.0
<i>CVS</i>	12,387.3	26,884.0	46,212.9	3,689.3

The frequency of fire (*FREQ*), or the return interval, and the weather category characteristics may change of the 100-year period due to fuel changes in the fire-shed, climate change, prevention and protection measures. They are held constant in this example. We have made a simple assumption regarding loss of carbon outside the fuel break but in the project area, which is 30% loss for an extreme fire event, 20% loss for a high severity fire, and 10% loss for a moderate event. These are low figures for areas with steeper slopes or lower in elevation where weather is more severe on average.

In all cases examined (table 35) the fuel break provided a positive carbon benefit. Holding other things constant it would take a fire frequency of .435% a year to reach a break even point between the carbon lost in the fuel break treatment and that

theoretically saved. These are conservative estimates because the carbon saved used the beginning period carbon stocks, which increased over time.

Discussion and Conclusions

Harvest scheduling for the improved forest management project type can be complex, even for smaller properties. This is due to trying to optimize additionality by simulating the baseline close to the FIA mean or starting inventory, depending on starting point. If you are conducting an economic analysis, such as maximizing NPV, then a flexible optimizing harvest schedule is even more desirable. Therefore, we recommend using an optimizing harvest schedule for improved forest management project types, such as a linear or dynamic program.

The inclusion of harvested wood products in the baseline accounted for reductions in harvest over the 100-year projection period. The secondary effects calculation applied an additional penalty of 20% of the reduced harvest to account for market leakage. The risk assessment analysis produced what appear to be reasonable results, but will have to be monitored over time to match long-term results by geographic region.

The contribution of wood products was relatively small or even negative for the scenarios presented. This might have been different if there was more harvesting, especially over a larger area with a mix of age classes where harvests could be offset with on-site growth and not cause a reduction in CRTs. Improvements in stand growth could also change the contribution of the harvested wood products pool. Both the baseline and project activity were projected using growth calibrations from the native lightly managed stands. Where group selections or clearcuts occur that create rapidly growing thrifty stands, wood products contributions could greatly increase. This would be captured over time with inventories and would ultimately be reflected in CRTs. Therefore, the CRT projections for these scenarios are conservative.

The application of the reforestation project type was found to be appropriate for both private and public lands, but not economically viable without subsidy. The improved forest management project type was not found to be appropriate for these projects as public lands, as the baseline could not be shown to differ from the project activity. Improved forest management project types on private lands had economic returns (NPV) of \$217 and \$649 per acre (\$536 and \$1,603 per hectare) for the two demonstration project areas assuming a price of \$9.00 a tonne CO₂e. At \$20.00 a tonne CO₂e the NPVs were \$585 and \$1,568 per acre (\$1,445 and \$3,873 per hectare). The higher value resulted from the starting inventory being substantially above the mean for the assessment area, which resulted in CRTs being immediately created.

The use CVal (Bilek et al. 2009) rapidly produces an economic analysis of a project based on carbon income and project costs. This software provides an excellent example of the type of analytic tools needed to build rational ecosystem services markets.

The analysis of the effects of a fuel reduction project showed that the project appeared beneficial to carbon management. More work is needed in this area as it is the application of stochastic landscape disturbances to project specific areas. Quantification necessarily involves estimates of disturbance and weather probabilities from historical records and local knowledge and estimates of fire severity, for both treated and untreated conditions.

Appendix I: LDSF Inventory, Biomass Calculations and Growth Projections

Inventory and projection methods will be discussed below with results provided in the appropriate sections in the main body of the report. A description of the inventory, biomass calculations, carbon conversions and growth projection methodologies will be provided here since they apply uniformly to both project areas and the private as well as the public scenarios.

Inventory

LDSF maintains two inventories across the entire Forest. The first is a continuous forest inventory (CFI) that consists of 221 permanent plots or approximately one plot per 40 acres. These plots were established in 1964/5 and have been measured, with one exception, every five years. The second inventory consists of temporary plots and is called the timber atlas inventory (TAI). These two data sets provide a level of information and intensity that is not typical for most forestlands, but provide useful data for a demonstration and research forest such as this.

CFI Overview

The CFI is based on 221 permanent plots on a systematic grid across the Forest. The plots are probability proportional to size (the larger the tree the larger the probability of inclusion on the plot, at a given distance from plot center) and use a basal area factor (BAF) of 15 ft²/acre (3.44 m²/hectare). Tree species, diameter at breast height (dbh) to the nearest 0.1 inch (0.25 cm), crown ratio, and condition are recorded for each measured tree. A subsample of total tree height is collected. The data is stored in a Microsoft Access database.

TAI Overview

The TAI inventory is a multi-resource inventory that evolved over time from an inventory originally designed for timber and tax purposes in the 1960s. There are approximately 3,600 current plots across the forest, on a 16-plot systematic grid within 40-acre (16.2 h) units called lots. The plots are probability proportional to size and use a basal area factor (BAF) of 20 ft²/acre (4.59 m²/hectare). Tree species, dbh to the nearest 2.0 inches (5.08 cm), and crown ratio were recorded for each measured tree. A subsample of total tree height, breast height age, and crown radius was collected. A small tree subplot was sampled. Shrub species, height and cover; standing dead and lying dead wood was estimated with dimensions and decay class variables. An estimate of canopy cover was made by taking a sighting tube shot at each plot center and between each plot, recording the tree canopy intersections. Shrub information was also collected at each intermediate plot. Other wildlife habitat information was collected for each plot. The data was stored in a Microsoft Access database.

Inventory Workup

The TAI inventory was used in conjunction with a type map to provide the carbon estimates and growth projections for both projects. For the above-ground live carbon pool, each tree record's data was input into the FIA standard biomass functions. Only trees 5 inches (12.7 cm) dbh and above were included in the analysis. The steps and appropriate functions for the most common species present are shown below.

Step 1, calculate the bole volume: The bole volume calculation is shown for each species using a 20-inch (50.80 cm) dbh tree and a total height (THT) of 80 feet (24.4 m). The volume assumes a ground to tip bole, no stump or tip deduction. These equations, cubic volume total stem (CVTS), are from the document *Volume estimation for the PNW-FIA Integrated Database* (dated 13 May 2009).

Ponderosa pine (Equation #5): $CVTS(DBH=20 \text{ in.}, THT=80 \text{ ft.}) = 64.5787 \text{ ft}^3$.

White fir (Equation #23): $CVTS(DBH=20 \text{ in.}, THT=80 \text{ ft.}) = 60.5337 \text{ ft}^3$.

Incense-cedar (Equation #19): $CVTS(DBH=20 \text{ in.}, THT=80 \text{ ft.}) = 50.8788 \text{ ft}^3$.

Douglas-fir (Equation #3): $CVTS(DBH=20 \text{ in.}, THT=80 \text{ ft.}) = 60.0552 \text{ ft}^3$.

Black oak (Equation #41): $CVTS(DBH=20 \text{ in.}, THT=80 \text{ ft.}) = 115.4407 \text{ ft}^3$.

Step 2, calculate the biomass of the bole: The bole, or stem or trunk, biomass is the volume of the wood multiplied by the wood density. Wood density is variable and average densities are reported by species or species groups. The wood densities below are from the *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine: $64.5787 \text{ ft}^3 \times 23.71 \text{ lbs/ft}^3 \times (1 \text{ lb.}/2.204622 \text{ kg}) = 694.5237 \text{ kg}$

White fir: $60.5337 \text{ ft}^3 \times 23.09 \text{ lbs/ft}^3 \times (1 \text{ lb.}/2.204622 \text{ kg}) = 633.9972 \text{ kg}$

Incense-cedar: $50.8788 \text{ ft}^3 \times 21.84 \text{ lbs/ft}^3 \times (1 \text{ lb.}/2.204622 \text{ kg}) = 504.0288 \text{ kg}$

Douglas-fir: $60.0552 \text{ ft}^3 \times 28.7 \text{ lbs/ft}^3 \times (1 \text{ lb.}/2.204622 \text{ kg}) = 781.8048 \text{ kg}$

Black oak: $115.4407 \text{ ft}^3 \times 34.94 \text{ lbs/ft}^3 \times (1 \text{ lb.}/2.204622 \text{ kg}) = 1,829.5637 \text{ kg}$

Step 3, calculate the biomass of the bark: The bark biomass is estimated directly from the tree DBH, THT and wood density although some species equations only use DBH. These functions may be found in the *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine (Equation #9): $BB(DBH=50.80 \text{ cm}, THT=24.4\text{m}) = 79.5466 \text{ kg}$

White fir (Equation #1): $BB(DBH=50.80 \text{ cm}) = 369.0422 \text{ kg}$

Incense-cedar (Equation #12): $BB(DBH=50.80 \text{ cm}) = 124.5344 \text{ kg}$

Douglas-fir (Equation #8): $BB(DBH=50.80 \text{ cm}) = 187.6330 \text{ kg}$

Black oak (Equation #30): $BB(DBH=50.80 \text{ cm}, THT=24.4\text{m}, \text{Density}) = 167.7698 \text{ kg}$

Step 4, calculate the biomass of the live crown branches: The live crown branches are computed from tree DBH and THT although some species equations only use DBH. These functions may be found in the *Regional biomass equations used by FIA to estimate bole, bark and branches* (dated 13 May 2009).

Ponderosa pine (Equation #7): $BB(DBH=50.80 \text{ cm}, THT=24.4\text{m}) = 178.3803 \text{ kg}$

White fir (Equation #1): $BB(DBH=50.80 \text{ cm}, THT=24.4\text{m}) = 91.0286 \text{ kg}$

Incense-cedar (Equation #10): $BB(DBH=50.80 \text{ cm}, THT=24.4\text{m}) = 239.9483 \text{ kg}$

Douglas-fir (Equation #6): $BB(DBH=50.80 \text{ cm}) = 110.4461 \text{ kg}$

Black oak (Equation #16): $BB(DBH=50.80 \text{ cm}) = 289.3839 \text{ kg}$

Step 5, sum the aboveground live tree biomass: The bole, bark and live branches are summed. The leaves or needles are not estimated here. Technically, much of the bole and bark is dead as much of the live portions are at the intersection of the two, but we lump these pools into the live component as the organism is alive.

Ponderosa pine: $(694.5237 \text{ kg} + 79.5466 \text{ kg} + 178.3803 \text{ kg})/1,000 \text{ kg/tonne} = 0.95 \text{ tonne}$

White fir: $(633.9972 \text{ kg} + 369.0422 \text{ kg} + 91.0286 \text{ kg})/1,000 \text{ kg/tonne} = 1.09 \text{ tonne}$

Incense-cedar: $(504.0288 \text{ kg} + 124.5344 \text{ kg} + 239.9483 \text{ kg})/1,000 \text{ kg/tonne} = 0.87 \text{ tonne}$

Douglas-fir: $(781.8048 \text{ kg} + 187.6330 \text{ kg} + 110.4461 \text{ kg})/1,000 \text{ kg/tonne} = 1.08 \text{ tonne}$

Black oak: $(1,829.5637 \text{ kg} + 167.7698 \text{ kg} + 289.3839 \text{ kg})/1,000 \text{ kg/tonne} = 2.29 \text{ tonne}$

Step 6, convert biomass to carbon estimate: The carbon content of biomass is approximately ½ or 50%.

Ponderosa pine: $0.95 \text{ tonnes biomass} \times 0.5 = 0.476 \text{ tonnes C}$

White fir: $1.09 \text{ tonnes biomass} \times 0.5 = 0.547 \text{ tonnes C}$

Incense-cedar: $0.87 \text{ tonnes biomass} \times 0.5 = 0.434 \text{ tonnes C}$

Douglas-fir: $1.08 \text{ tonnes biomass} \times 0.5 = 0.540 \text{ tonnes C}$

Black oak: 2.29 tonnes biomass X 0.5 = 1.143 tonnes C

Step 7, estimate below-ground carbon: The below-ground carbon was estimated using the protocol suggested reference by Cairns et al. (1997). The function is:

$$BBD = e^{-0.7747+0.8836*\ln(ABD)}$$

where ABD = above-ground biomass density in tonnes per hectare,

BBD = below-ground biomass density in tonnes per hectare.

This estimate is made for each plot so that it may be incorporated into the plot-level standard error estimates. The carbon is estimated by multiplying BBD by 0.5.

Step 8, estimate standing and lying dead wood for both project types: The TAI inventory provides estimates for both of these carbon pools. The specifications of the inventory are as follows.

- Minimum size of 10 inches (25.4 cm) diameter for snags, 8 inches (20.3 cm) diameter for down wood
- Species coded for snags where identifiable
- Decay classes of sound and rotten for both snag and down wood, down wood also has an intermediate class
- Length, small diameter and large diameter for down wood, dbh for snags.

The volume of the aboveground wood was estimated and then multiplied by a density factor that varied by species and decay class. The frustum of a paraboloid formula (1.2) was used to calculate volume for down wood (Husch et al. 1993). A neiloid formula (1.3) was used for snags, since only one measurement was taken (dbh) and that was near the base.

$$V = \frac{h}{2}(A_b + A_u) \quad (1.2)$$

$$V = \frac{1}{4}(A_b h) \quad (1.3)$$

where, A_b = cross-sectional area at the base,
 A_u = cross-sectional area at the top, and
 H = height or length.

The wood density used for snags was the same as that for the standing live trees, where the wood was sound. Where species was not identified for snags, white fir density was used as it was the most common species on LDSF. Rotten snags received a density of 0.202 g/cm³, which was the decay class 3 for down white fir in the Sierra Nevada

according to Harmon and Sexton (1996). Since snag height was not measured the height was estimated using the LDSF height-diameter functions used for live trees.

No estimates for bark biomass were made. The wood density for down wood used the white fir estimates for the Sierra Nevada from Harmon and Sexton (1996, see table 4). This was translated to be 0.340 g/cm³ for sound logs, 0.333 g/cm³ for intermediate logs, and 0.185 g/cm³ for rotten logs. Biomass estimates from dead wood was converted to carbon tonnes as in previous steps.

Step 9, calculate the standard error and percent error of the carbon estimate: The standard error is a common statistical parameter used to express the variability of an estimate. When expressed as a percent of the estimate it is known as the percent error. The standard error formula will be a function of the sampling design, which could be systematic with random start (treated as random), stratified, multi-stage, double, combinations of the above or other design. In this case we have a systematic grid of plots that have been overlaid on a type map yielding a stratified random sample. Each stand was treated as a separate stratum. The total and standard error formula are as follows (Husch et al. 1993).

Mean (live and dead tree carbon per acre) per stand or stratum: $\bar{x}_j = \frac{\sum_{i=1}^{n_j} x_{ij}}{n_j}$, where x_{ij} is

the above- and below-ground live tree and above-ground standing and lying tree carbon from the i^{th} tree on the j^{th} plot and n_j are the number of plots in the j^{th} stratum.

Mean (live and dead tree carbon) per project: $\bar{x} = \frac{\sum_{j=1}^M N_j \bar{x}_j}{N} = \sum_{j=1}^M P_j \bar{x}_j$,

where M is the number of strata (or stands), N_j is the number of sampling units in the j^{th} stratum, N is total number of sampling units in the population, and P_j is the proportion of the total forest area in the j^{th} stratum (N_j/N).

Total (live and dead tree carbon) per project: $\hat{X} = N\bar{x}$

Each stand or stratum stand variance (standard deviation squared) is calculated using the simple random sampling formula.

Variance of the mean per acre estimate for a stratum: $s_j^2 = \frac{\sum_{i=1}^{n_j} (X_{ij} - \bar{x}_j)^2}{n_j - 1}$

The variance estimate for the mean of the project, or population, assumes that the sample is small relative to the population so that the finite population correction may be ignored (a more conservative estimate).

Variance of the mean per acre estimate for project: $s_{\bar{x}}^2 = \sum_{j=1}^M P_j^2 \frac{s_j^2}{n_j}$

Variance of the carbon estimate for project: $s_x^2 = N^2 s_{\bar{x}}^2$

The standard error of the total is the square root of s_x^2 .

Step 10, estimate shrub carbon for reforestation units: The carbon contained in the vegetation removed from a site when conducting a reforestation project type must be estimated. This was done by using shrub biomass estimates from Martin et al. (1981) for live and dead aboveground material. Two species were available from this paper, greenleaf manzanita (*Arctostaphylos patula*) and snowbrush (*Ceanothus velutinus*). To be conservative, other species used the manzanita estimates since they were the larger of the two. The biomass estimates were provided by percent cover in 10% classes. Cover estimates from field plots that were installed pre-treatment were used to estimate the biomass.

Herbaceous cover is also required but is rare, in a carbon inventory sense, in these brushfields. Indirect estimations of emissions from mobile combustion preparing and planting the site are taken from the protocols (FPP table 6.1). The reforestation in the McMullen Mountain project was in heavy brush using mastication to clear it; therefore a heavy emission is appropriate, given as 0.429 tonnes per acre CO₂e. This equates to 0.117 tonnes per acre C. The reforestation unit in the Sunset project was sprayed, brush raked, and piled. Since the brush was also dense and large the heavy emission amount of 0.117 tonnes per acre C will also apply. No emissions from shifting from croplands occurred.

The results of this analysis are shown in tables 4 and 15 for the Sunset and McMullen Mountain projects respectively. The reforestation components did not have any aboveground live tree components; therefore the tree calculations were not performed for that project type. Shrub carbon removed was estimated for the reforestation types only. The biomass functions used for the projections of both baseline and project activity were the same as the FIA functions.

Growth Projections

The growth projections used the same modeling methods as for the LDSF option-A plan (CCR 933.13), which is a state-approved long-term (100 years) harvest schedule to demonstrate sustained yield. The project activity projections are the same as that presented in the option-A plan; for both the private and public lands scenarios.

Growth data from the CFI plots was used to calibrate the diameter growth component of the Forest Vegetation System (FVS) variant ICASCA (Dixon 1999), by species. This growth simulator was used within the Landscape Management System (LMS) version 2.0.46 (Robards and Smith 2006). LMS provided an integrated system for growth projections, harvest simulation, statistical reports, stand visualization and carbon yield reporting. Figure 1 shows the key file that was used with every simulation in this report. The BFVOLUME keyword sets the merchantable volume at a minimum 10-inch dbh, 6 inch top and 1 foot stump. At least 3,000 board feet per acre must be available to harvest economically. The BAIMULT keyword is the LDSF growth calibration factors. The BFVOLUME keyword sets hardwood species to zero board foot volume.

```

File: C:\PROJ\Carbon\LaTourDemo\CMAIAAnalysis\LDSF.KEY  4/15/2007, 6:53:32PM
1 COMMENT
2 DEFAULT KEY FILE FOR LATOUR HARVEST SCHEDULE 2006. TA ROBARDS.
3 KEYWORD 111111111 222222222 333333333 444444444 555555555 666666666 777777777
4 END
5 BFVOLUME 10.0 6.0 1.0
6 MINHARV 3000.0
7 BAIMULT 0 DF 2.52
8 BAIMULT 0 PF 2.26
9 BAIMULT 0 SF 1.45
10 BAIMULT 0 WF 1.62
11 BAIMULT 0 LP 6.07
12 BAIMULT 0 WF 1.40
13 BAIMULT 0 RF 1.23
14 BAIMULT 0 IC 2.83
15 BAIMULT 0 BO 6.15
16 BFVOLUME 0 BO 999
17 BFVOLUME 0 TO 999
18 BFVOLUME 0 MH 999
19 BFVOLUME 0 PY 999
20 BFVOLUME 0 WO 999
21 BFVOLUME 0 BM 999
22 BFVOLUME 0 RA 999
23 BFVOLUME 0 MA 999
24 BFVOLUME 0 GC 999
25 BFVOLUME 0 CL 999
26 BFVOLUME 0 OH 999

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Page: 1

Figure 31. FVS key file used in the simulations.

While carbon pool estimates were available from within LMS, based primarily on Jenkins et al. (2003), we used the FIA biomass functions for both baseline and project activity projections. This was done by post-processing the inventory data files by 5-year periods using the custom-made California Carbon Cruncher program (Robards 2009). This accounted for both above-ground and below-ground carbon. Dead wood was simulated using the LMS defaults for dead wood decay over time, but were found to estimate very little down or standing dead wood over time. Since this would cause an

underestimation in the baseline and therefore an overestimation in additionality over time, an average down wood component was estimated from published fuel loading for down dead wood that was 3.1 inches (7.9 cm) or larger (Blonski and Schramel 1981; FMA 2009). Table 36 shows the default values that were used by forest type and size class. The ratio of long-term average projected snag to down wood biomass was assumed to be 1:1.

Table 36. Default down wood density by forest type and size class (class 2: 5-11" (12.7-28.0 cm) dbh, class 3: 12-20" (30.5-50.8 cm) dbh, 4: >20" (50.8 cm) dbh).

Forest Type	Size Class	DDW 3.1"+ (tons biomass per acre)	DDW 3.1"+ (tonnes C per acre)
Ponderosa pine	2	4.9	2.2
Ponderosa pine	3	3.2	1.4
Ponderosa pine	4	6.5	2.9
White fir	2	2.2	1.0
White fir	3	6.7	3.0
White fir	4	7.8	3.5
Red fir	3, 4	1.8	0.8
Lodgepole pine	2	2.2	1.0
Lodgepole pine	3	6.1	2.8
Mixed Conifer, Fir	4	6.6	3.0
Mixed Conifer, Pine	4	5.2	2.4

The wood products estimates for the baseline require that a volume estimate be obtained from the simulations, which was taken from LMS. Then the merchantable cubic foot volumes were multiplied by the density factor of 24.59 lbs/ft³ and then converted to tonnes of C by multiplying by ½ and dividing by 2,240 pounds. The wood product class was estimated to be 70% softwood plywood and 30% softwood lumber based on the last two timber sales from the Forest (Ben Rowe, CAL FIRE, personal communication). Therefore, a .470 factor for softwood lumber and a 0.490 factor for softwood plywood were applied for in-use. A 0.294 and a 0.283 factor were applied for landfills, respectively.

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