Effectiveness and longevity of fuel treatments in coniferous forests across California

Managers' Report: Modoc National Forest

Prepared by

Nicole Vaillant, Fire Ecologist, nvaillant@fs.fed.us, USDA Forest Service, Western Wildland Environmental Threat Assessment Center

Erin Noonan-Wright, Fire Application Specialist, enoonan02@fs.fed.us, USDA Forest Service, Wildland Fire Management Research Development and Applications

Scott Dailey, Fire Ecologist, scottdailey@fs.fed.us, USDA Forest Service, Adaptive Management Services Enterprise Team

Carol Ewell, Fire Ecologist, cewell@fs.fed.us, USDA Forest Service, Adaptive Management Services Enterprise Team

Alicia Reiner, Fire Ecologist, alreiner@fs.fed.us, USDA Forest Service, Adaptive Management Services Enterprise Team

Kevin McCrummen, Biological Science Technician, kmcrummen@fs.fed.us, USDA Forest Service, Adaptive Management Services Enterprise Team

JFSP Grant 09-1-01-1

Table of Contents

Background

Longevity of fuel treatment effectiveness to alter potential fire behavior is a critical question for managers preparing plans for fuel hazard reduction, prescribed burning, fire management, forest thinning, and other land management activities. Results from this study will help to reduce uncertainty associated with plan prioritization and maintenance activities. From 2001 to 2006, permanent plots were established in areas planned for hazardous fuel reduction treatments across 14 National Forests in California. Treatments included prescribed fire and mechanical methods (i.e., thinning of various sizes and intensities followed by a surface fuel treatment). After treatment, plots were re-measured at various intervals up to 10 years post-treatment. Very few empirically based studies exist with data beyond the first couple of years past treatment, and none span the breadth of California's coniferous forests. With the data gathered, this research aimed to meet three main objectives:

Objective 1) *Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior, by*

a) measuring effects of treatments on canopy characteristics and surface fuel loads over time, and
b) modeling potential fire behavior with custom fuel models.

Objective 2) *Quantify the uncertainty associated with the use of standard and custom fuel models.*

Objective 3) *Assess prescribed fire effects on carbon stocks and validate modeled outputs.*

This managers' report is meant to compliment the final report to the Joint Fire Science Program and supply project specific information that is not included in the regional assessment. This report includes a summary of Key Findings and Management Implications from the regional study as well as individual Forest-level information for each plot (i.e., project history, map, navigation directions, plot level findings, and plot protocol). For your use, we included a number of supplementary files with the digital version of this report. Included on the thumb drive are the following also described in Appendix A:

- Final report to the JFSP
- FVS Input database for your Forest for all projects (database file)
- Photo pairs for the plots on your Forest (power point file)
- Plot maps for each project on your Forest (pdf file)
- GIS shapefile with the plots on your Forest

All datasets for the regional project were input into the FFI (Feat/FIREMON Integrated) tool (www.frames.gov/partner-sites/ffi/ffi-home/) for future use and comparisons. Please contact Nicole Vaillant (nvaillant@fs.fed.us) for more information on obtaining the FFI data or other questions.

Key Findings

Objective 1- Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior by measuring effects of treatments on canopy characteristics and surface fuel loads over time and modeling potential fire behavior with custom fuel models.
Results have shown initial reductions in surface fuels from fire treatments recover to pre-treatment levels by 10 yr post-treatment. Mechanical treatments continue to have variable effects on surface fuels. With the exception of mechanical treatments in red fir, both treatment types resulted in increased live understory vegetation by 8 yr post-treatment relative to pre-treatment. Mechanical treatment effects on stand structure remains fairly consistent through 8 yr post. Fire-induced delayed mortality contributes to slight decreases in canopy cover and canopy bulk density over time. For both treatment types, overall canopy base height decreases in later years due to in-growth of smaller trees, but it remains higher than pre-treatment. The changes in fuel loads and stand structure are reflected in fire behavior simulations via custom fuel modeling. Surface fire flame lengths were initially reduced as a result of prescribed fire, but by 10 yr post-treatment they exceeded the pre-treatment lengths. Though a low proportion of fire type, initial reductions in potential crown fire returned to pre-treatment levels by 8 yr post-treatment; passive crown fire remained reduced relative to pre-treatment for the duration. Mechanical treatments showed variable and minimal effects on surface fire flame length over time; however the incidence of active crown fire was nearly halved from this treatment for the duration.

Objective 2- Quantify the uncertainty associated with the use of standard and custom fuel models
The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) was used to model potential fire behavior for plots treated with prescribed fire to determine the differences in modeled fire behavior using standard and custom fuel models. In general predicted fire behavior from custom versus standard fuel models were similar with mean surface fire flame lengths slightly higher using standard fuel models for all time steps until the 8 yr post-treatment. Similarly, custom fuel models predicted a higher instance of surface fire than standard fuel models with the exception of 8 yr post-treatment.

Objective 3- Assess prescribed fire effects on carbon stocks and validate modeled outputs.
To better understand the impact of prescribed fire on carbon stocks, we estimated aboveground and belowground (roots) carbon stocks using field measurement in FFE-FVS, and simulated wildfire emissions, before treatment and up to 8 yr post-prescribed fire. Prescribed fire treatments reduced total stand carbon by 13%, with the largest reduction in the forest floor (litter and duff) pool and the smallest reduction in the live tree pool. Combined carbon recovery and reduced wildfire emissions allowed the initial carbon source from simulated wildfire emissions and treatment to become a sink by 8 yr post-treatment relative to pre-treatment if both were to burn in a wildfire. In a comparison of field-derived versus FFE-FVS simulated carbon stocks, the total stand, tree, and belowground live carbon pools are highly correlated. However, the variability within the other carbon pools compared was high (up to 212%).

Management Implications

- ✓ Need more long term monitoring.
- ✓ The ability of a fuel treatment to maintain effectiveness in reducing fire behavior and effects depends on the accumulation rates and distribution of fuels, which are used as metrics to judge treatment longevity. Surface and understory fuel loading trends help inform managers' initial treatment and maintenance timelines, priorities, and adaptive management prescriptions.
- ✓ Stand and canopy structure trends help inform both fuel and silviculture integrated objectives and prioritizations.
- ✓ Despite extensive variability between plots, overall trends for treatment-forest combinations exist.
- ✓ Changes to modeled surface fire after prescribed fire treatment included an initial decrease in surface fire flame lengths, then an increase starting around 5 yr post-treatment.
- ✓ Overall, modeled fire behavior in mechanical treatments showed that goals of reduced fire behavior were initially reached, and then began diminishing around 5 to 8 yr post-treatment, with some positive changes still apparent through 8 yr post-treatment.
- ✓ In general, predicted fire behavior from custom versus standard fuel models was similar.
- ✓ Prescribed fire treatments reduced total stand carbon by about 13%, and total stand carbon stocks returned to 97% of pre-treatment levels after 8 yr post-treatment.
- ✓ Although the total stand carbon differences between field-derived and simulated carbon stocks are minimal, the variability within different carbon was great.

Project Websites

Please visit our project website in the next few months to year as reports are finalized and publications become available at http://www.fs.fed.us/adaptivemanagement/pub_reports/JFS_vaillant2.shtml.

The final report and many of our presentations and other deliverables will also be available via the Joint Fire Science Program website at http://www.firescience.gov/JFSP_advanced_search_results_detail.cfm?jdbid=%24%26Z%2F8W%20%20%20%0A.

Acknowledgements

We acknowledge funding for this research from the USFS Region 5 Fire Aviation and Management and Joint Fire Sciences program (JFS 09-01-1-01). This project would have never gotten off the ground without the passion and drive of Jo Ann Fites-Kaufman. We thank the countless number of field crew members over the past 12 years, especially T. Decker and K. McCrummen for serving as crew leads during the past four years. Thank you to all the fire and fuels specialists on all the National Forests in California for providing invaluable insight and information about their fuel treatments.

Hackamore (Project 921, Devil's Garden District)

Project history

The Hackamore project had three plots set up pre-treatment using the 2001 detailed plot style. For details about the protocol used, please see "Appendix B: Sampling Protocol" at the end of the report. Plots were sampled prior to treatment (P00), then 1 yr post (P01), 2 yr post (P02), 8 yr post (P08), and 10 yr post-treatment (P10) (Table 1).

For analysis at the regional level, plots from all projects were grouped into one of two treatment types (mechanical or prescribed fire) and one of three dominant forest types (yellow pine, red fir, or mixed conifer). All Hackamore plots were grouped into the prescribed fire treatment category and the yellow pine forest type.

The Timber Mountain RAWS was used for fire weather and fire behavior simulation modeling.

Table 1. Treatment visits completed by year for each of the plots in the project. ~ Indicates that data were not collected on plots at during those years.

Plot	2002	2003	2004	2005	2010	2011	2012
1	P00	P01	P02	~	P08	~	P10
2	P00	P01	P02	~	P08	~	P10
3	P00	~	P01	P02	~	P08	~

Treatment information

Prior treatment: A pre-commercial thin in occurred in 1978 in the area around the plots.

During the project treatment: Plots 1 and 2 were burned in spring of 2003. Plot 3 was burned in June of 2004; it was still smoldering when the field crew did the 1 yr post re-read.

Future treatment: No plans for additional underburn treatments are scheduled for this unit. The unit is proposed to be mechanically thinned under the Knobcone EA Thinning project scheduled for June 2012.

Project location map

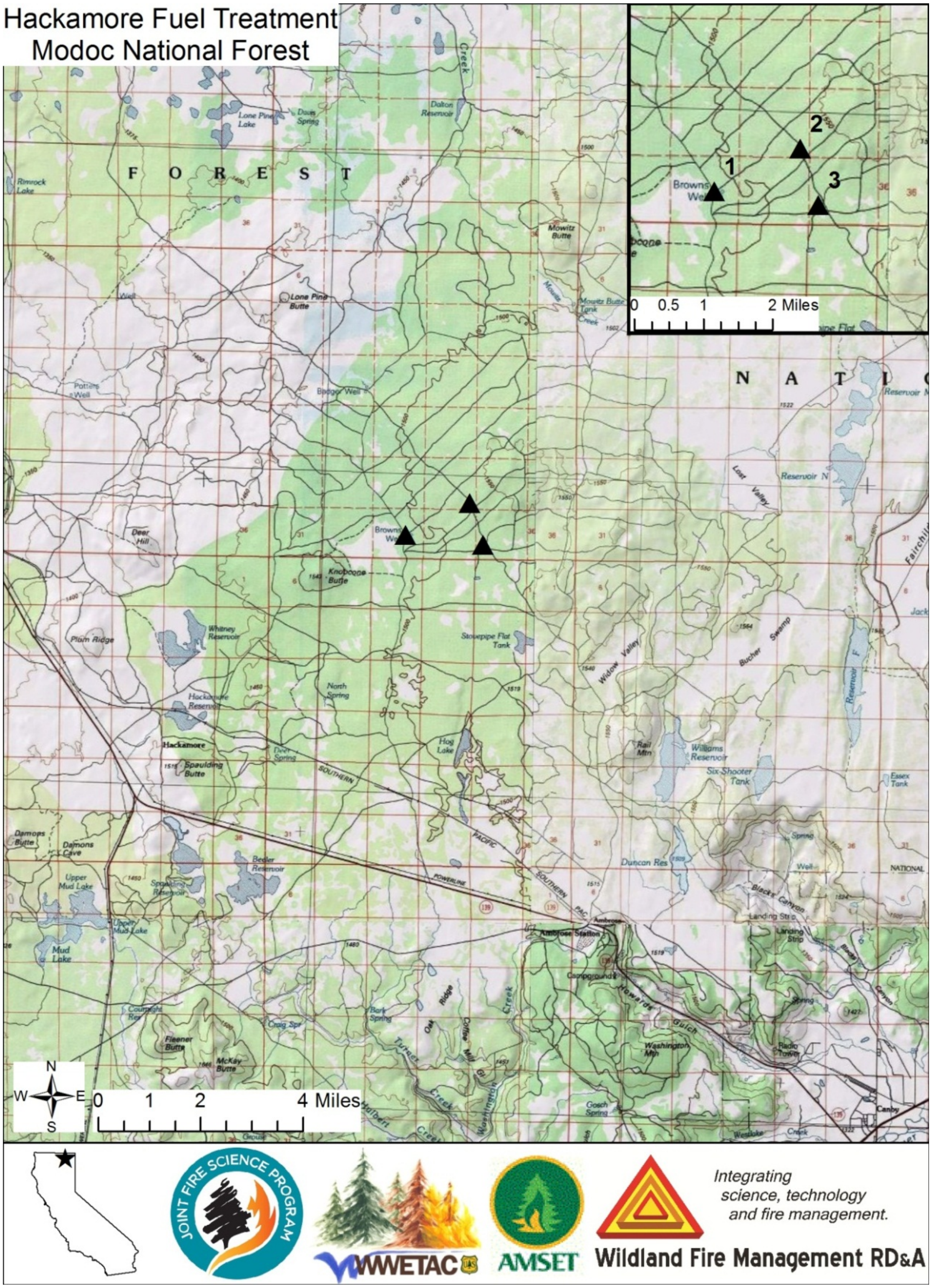


Figure 1. Location map for the Hackamore fuel treatment monitoring plots, showing general location of plots, and inset displaying increased detail of plot locations.

Driving directions/GPS/plot layout

Driving directions

Plot 1- From Highway 139 turn right (NE) onto 44N11 and start odometer here. Cross railroad tracks at 1.4 miles, veer left at intersection with 43N80 and 43N79 at 2.3 miles. Turn right on road 44N45 at 6.55 miles. The start tree is located on the right (SE) side of 44N45 at about 12 m from the road edge.

Plot 2- From Highway139 turn right (NE) onto 44N11 and start odometer here. Cross railroad tracks at 1.4miles, veer left at intersection of 43N80 and 43N79 at 2.3miles. Turn right on 44N45 at 6.6miles. Turn right on 44N45C (an old road with trees down) at 8.1miles. Start tree is on right side at 8.5 miles at about 2 m from the road edge.

Plot 3- From Hwy 139 turn onto 42N60 (south side of 139) and start odometer here. Drive 1.35 miles and then turn left on 42N21. Drive 0.7 miles then turn left on 42N07. Drive 0.35 miles to start tree on left (East) side of 42N07. Start tree is 8 m from side of road; is a 43 cm DBH incense cedar in a cluster of small ponderosa pine.

Table 2. Directions (distance and azimuth) for walking from the "start tree" to each plot. The azimuth takes into account the local declination. Distance and azimuth are approximate as they were recorded by crews walking in from the start tree (usually tagged tree near road edge).

Plot	Start tree (DBH and species)	Azimuth °	Distance
1	Ponderosa pine	149	44 m
2	Ponderosa pine	272	34 m
3	43 cm incense cedar	78	44 m

Table 3. GPS coordinates for each plot (decimal degrees, datum NAD 1983, projection NAD_1983_California_Teale_Albers).

Plot	Longitude	Latitude
1	-121.049612	41.60946
2	-121.025733	41.618627
3	-121.020565	41.020565

Table 4. Plot layout line azimuths (degrees). See Appendix A for plot diagrams. CD is the main transect and F1 through F4 are the fuels transects.

Plot	Plot Type	AB	CD	F1	F2	F3	F4
1	Detailed 2001	289	19	59	149	239	329
2	Detailed 2001	337	247	112	22	292	202
3	Detailed 2001	44	78	174	264	355	86

Paired pictures

Below is an example of pictures paired or matched over the time steps the plots were visited. All of the paired pictures are available in the supplied power point file.

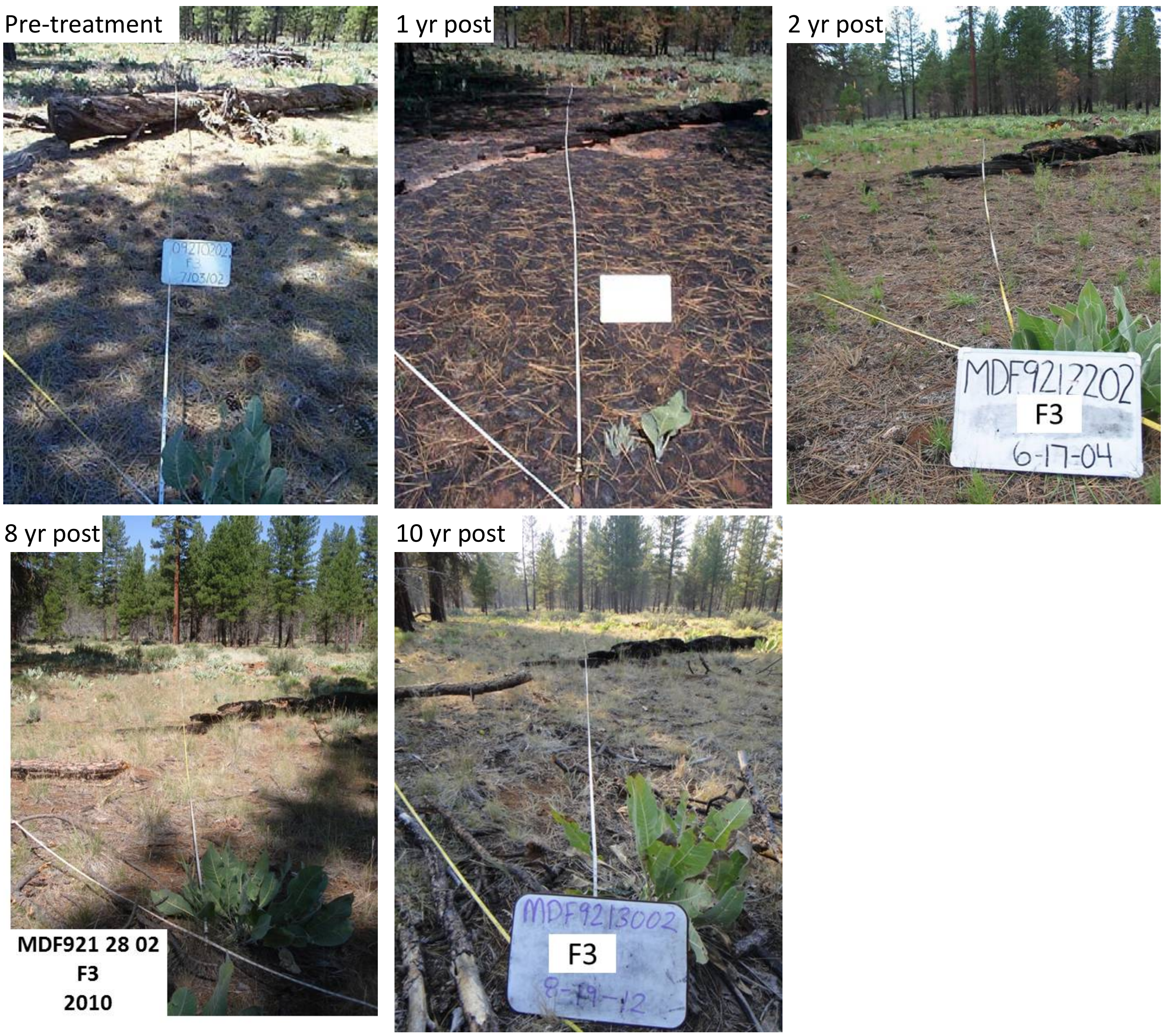
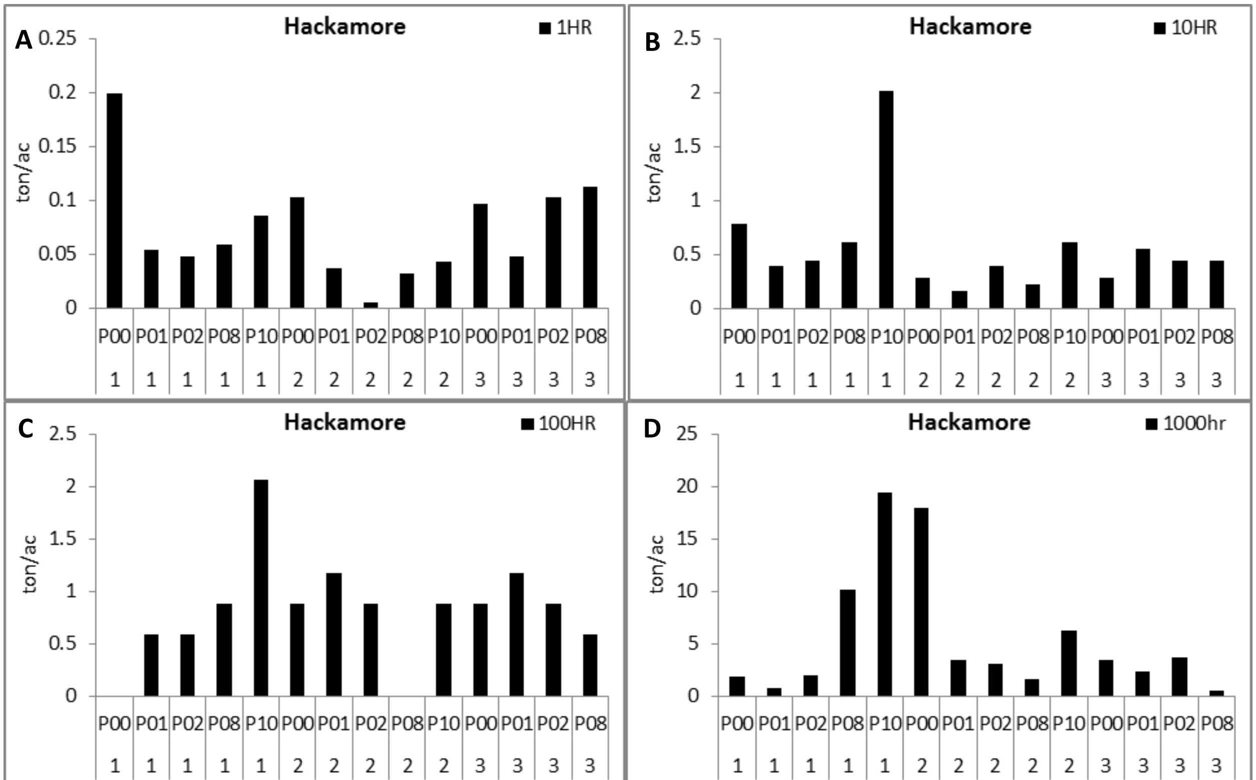


Figure 2. Example paired photos showing changes over the time steps for Plot 2, fuel line 3 (F3) from pre-treatment in 2002 through 10 yr post-treatment in 2012.

Plot findings

Below are graphs and data tables of key metrics from the data gathered in the field for each plot and time period within the project.



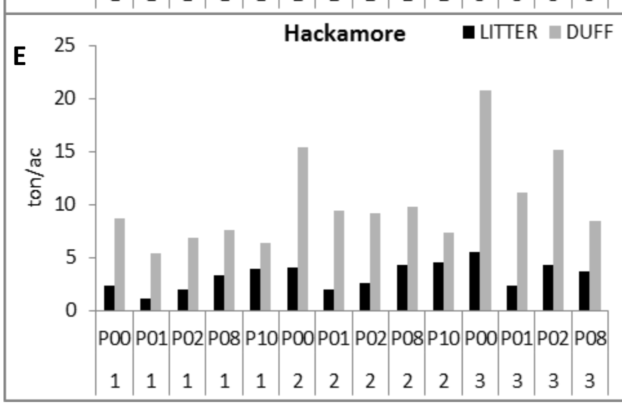


Figure 3. Fuel loading (ton/ac) for the 1-hr (A), 10-hr (B), 100-hr (C), and 1000-hr (D) time lag fuel classes, and litter and duff (E) for each plot at each sampling time period.

P00-pre-treatment, P01-1 yr post-treatment, P02-2 yr post-treatment, etc.

Table 5. Fuel loading (ton/ac) for the 1-hr, 10-hr, 100-hr, and 1000-hr time lag fuel classes, and litter and duff by time period for all the plots in the Hackamore fuel treatment project.

Plot	Time period	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
1	P00	0.20	0.8	0.0	1.8	2.3	8.7
1	P01	0.05	0.4	0.6	0.8	1.2	5.5
1	P02	0.05	0.4	0.6	2.1	2.0	6.9
1	P08	0.06	0.6	0.9	10.2	3.3	7.6
1	P10	0.09	2.0	2.1	19.4	4.0	6.4
2	P00	0.10	0.3	0.9	18.0	4.1	15.5
2	P01	0.04	0.2	1.2	3.4	2.0	9.4
2	P02	0.01	0.4	0.9	3.1	2.6	9.2
2	P08	0.03	0.2	0.0	1.7	4.4	9.8
2	P10	0.04	0.6	0.9	6.3	4.6	7.4
3	P00	0.10	0.3	0.9	3.5	5.5	20.8
3	P01	0.05	0.6	1.2	2.4	2.4	11.2
3	P02	0.10	0.4	0.9	3.7	4.3	15.1
3	P08	0.11	0.4	0.6	0.5	3.7	8.4

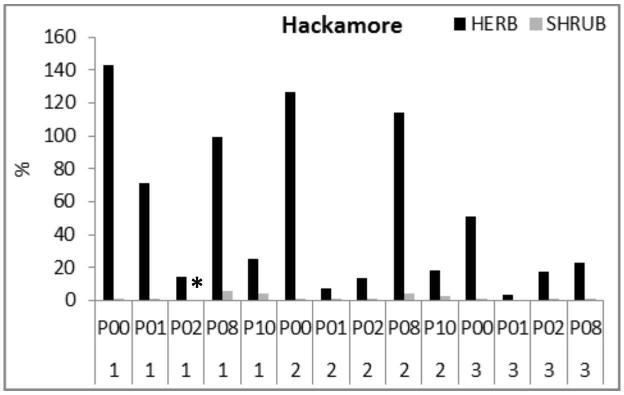
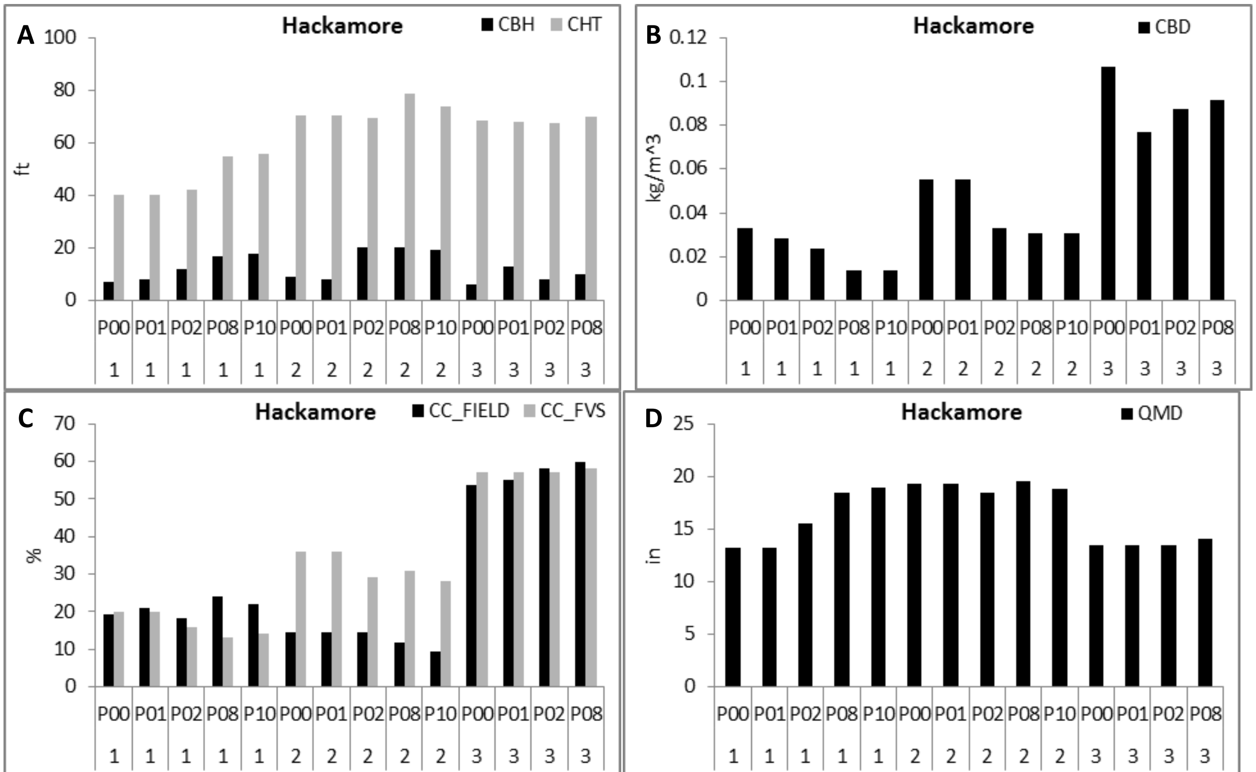


Figure 4. Average herbaceous plant and shrub cover for each plot at each sampling time period.

*Indicates the data was not collected for the given plot and time period (see Table 6).

Table 6. Understory vegetation cover by time period for all the plots in the Hackamore fuel treatment project. *Indicates the data was not collected for the given plot and time period.

Plot	Time period	Herbaceous cover (%)	Shrub cover (%)
1	P00	143	1
1	P01	71	1
1	P02	14	*
1	P08	99	6
1	P10	25	4
2	P00	127	1
2	P01	8	1
2	P02	13	1
2	P08	114	5
2	P10	18	3
3	P00	51	0
3	P01	3	0
3	P02	18	0
3	P08	23	1



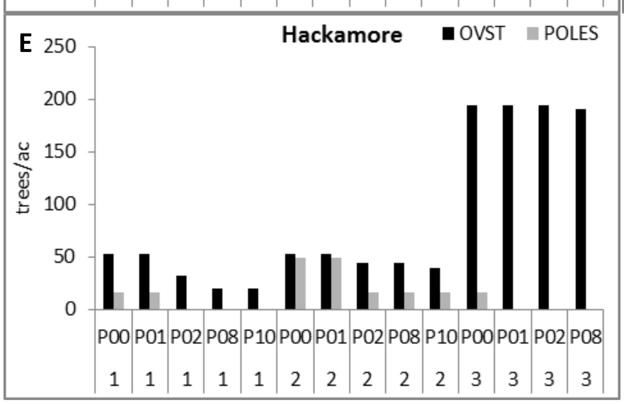


Figure 5. Canopy height and canopy base height (A), canopy bulk density (B), canopy cover from field data and FVS (C), quadratic mean diameter (D), and overstory and pole-sized tree density (E) for each plot at each sampling time period.

Table 7. Canopy characteristics by time period for all the plots in the Hackamore fuel treatment project.

Plot	Time period	Canopy cover (%) - field	Canopy cover (%) - FVS	Canopy height (ft)	Canopy base height (ft)	Canopy bulk density (kg/m^3)	Quadratic mean diameter (in)	Overstory (trees/ac)	Pole-sized (trees/ac)
1	P00	19	20	40.2	7.0	0.033	13.2	53	16
1	P01	21	20	40.2	8.0	0.028	13.2	53	16
1	P02	18	16	42.0	12.0	0.024	15.6	32	0
1	P08	24	13	54.8	17.0	0.014	18.4	20	0
1	P10	22	14	56.0	18.0	0.014	18.9	20	0
2	P00	15	36	70.2	9.0	0.055	19.4	53	49
2	P01	15	36	70.2	8.0	0.055	19.4	53	49
2	P02	14	29	69.3	20.0	0.033	18.4	45	16
2	P08	12	31	78.7	20.0	0.031	19.6	45	16
2	P10	9	28	73.8	19.0	0.031	18.8	40	16
3	P00	54	57	68.3	6.0	0.107	13.5	194	16
3	P01	55	57	68.2	13.0	0.077	13.5	194	0
3	P02	58	57	67.7	8.0	0.087	13.5	194	0
3	P08	60	58	69.8	10.0	0.092	14.1	190	0

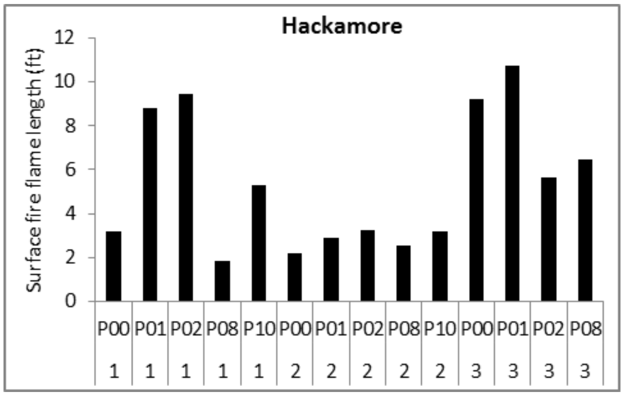


Figure 6. Surface fire flame length from custom fuel models using NEXUS for each plot at each sampling time period under 90th percentile fire weather conditions.

Table 8. Surface fire flame length (modeled in NEXUS with custom fuel models) and type of fire for 90th percentile fire weather conditions for all the plots in the Hackamore fuel treatment project.

Plot	Time period	Surface fire flame length (ft)	Type of fire
1	P00	3.20	Passive crown
1	P01	8.82	Passive crown
1	P02	9.43	Surface
1	P08	1.86	Passive crown
1	P10	5.29	Surface
2	P00	2.2	Passive crown
2	P01	2.88	Surface
2	P02	3.27	Surface
2	P08	2.53	Passive crown
2	P10	3.18	Surface
3	P00	9.19	Conditional crown
3	P01	10.71	Conditional crown
3	P02	5.66	Conditional crown
3	P08	6.47	Conditional crown

Appendix A: Description of Supplied Files

For your use we included a number of supplementary files with the digital version of this report (see the supplied thumb drive).

Final report to the JFSP

We included a digital version of the Final Report we submitted to the Joint Fire Science Program for the entire regional assessment.

FVS input database

For each Forest we included an FVS-ready database with all the plots from all the projects (*.mdb). The database includes two different StandInit and TreeInit tables depending on the plot types within the Forest; separate StandInit and TreeInit tables were created for the “detailed” plots and the “fuels” plots. We did this so one would not assume there was tree data available for all plots when it might not have been sampled. The fuel loading data was collected on all plots and is included by size class in both StandInit tables. For the detailed plots, the tree data collected is within the TreeInit table. For the fuels plots, a “dummy” tree list (a single white fir seedling) was created so the plots can be run through FVS, but caution should be used with these because of the lack of real tree data. If data was missing it is represented as a blank in the data tables.

Photo pairs

Most of the photos taken for each plot is included in the supplied Power Point file (*.pptx). Photos were taken along the main transect line(s) and fuel lines each time the plot was visited.

Plot maps

In addition to the imbedded maps in this report, we have supplied PDF versions of the project maps.

GIS shapefile

We supplied a GIS file with all the plots for the Forest.

Appendix B: Sampling Protocol

Data collection protocol (inclusive of all plot layouts)

Plot information naming example

1. Forest name: *"Tahoe NF"*
2. Forest ICS code: *"TNF"*
3. Project name: "Jaybird"
4. Project number: pre-determined for tracking purposes
5. Status: P00=pre-treatment, P01=1st year post, P02=2nd year post, etc.
6. Plot number: *"1"*
7. Surveyors: *"last name, first initial"*
8. Date: *"5/8/09"*
9. Notes: general notes about the area, treatment, anything that stands out

Shrub transect(s) (50 m)

Collect shrub information (for any shrubs that intersect the transect tape) along the length of the transect(s): transect, species, status (live/dead), shrub range in decimeters (dm, distance along transect, i.e. 0.6-0.9 m=3 dm), average height (cm).

Herbs (1x1 m quadrats)

Collect herbaceous species information for all plants rooted in the quadrat. Record the transect, frame, life form (fern, forb, grass, vine, other, unknown), status (live/dead), average height (cm), species (if you know it), and cover class (1=0-5%; 2= 6-25%; 3= 26-50%; 4=51-75%; 5=76-95%; 6=96-100%). Also please take general botany notes for the plot, such as species observed in the plot overall but not captured in the quadrats, and general observations about how much of the plot has weeds or herbaceous plant dominance.

Seedlings (<2.5 cm DBH)

Tally seedlings by species code, status (live/dead), and height class (15=1-15 cm; 30=16-30 cm; 60=31-60 cm; 100=61-100 cm; 200=101-200 cm; 300=201-300 cm, etc.).

Pole-sized trees (>2.5 to <15 cm DBH, and > 4.5 ft (1.37 m) tall)

Live poles: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D=dominant, CD=codominant, I=intermediate, S=suppressed).

Dead poles: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Overstory trees (>15 cm DBH and > 4.5 ft (1.37 m) tall)

Live trees: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D, CD, I, S).

Dead trees: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Canopy cover

Collect and record canopy cover, using the moosehorn (canopy sight tube) along the main transects (AB and/or CD) every 1m, starting at 1m and ending at 50m. The moosehorn should be held at the meter mark on the tape, standing on the side of the shrub transect opposite to the side where the herb quadrats are being place. Count the number of hits or intersections, out of 25, where canopy overlaps the grid intersections.

Fuel loading

Each planar fuel transect is 50 ft in length and information is gathered to characterize surface and ground fuels and fuel bed depth.

Surface fuels (1, 10, 100, 1000-hr)

Record the project, plot, transect and tallies for small fuel classes (1, 10, 100-hr), and take notes on the **dominant trees or shrub species** contributing to the fuel load for each transect.

Tally: 1-hr (>0.25") from 0-6 ft, 10-hr (0.25-<1") from 0-6 ft, 100-hr (1-<3") from 0-12 ft.

Record the species, diameter (cm), and status (rotten/sound) for each 1000-hr (> 3') from 0-50 ft.

Ground fuels (litter/duff/chips)

Measure and record litter and duff depth (thickness) measurements to the nearest 1 cm (measure thickness of each layer, not depth from surface). Starting at 1 foot, take 10 readings, one every 5 ft on each transect: (1 ft, 5 ft, 10 ft… 45 ft). Duff begins where the litter layer organic materials have begun to decompose, and duff ends where the composition is greater than 50% mineral soil. If a sampling spot lands exactly on a log, rock, or other obstruction, take the reading immediately adjacent to the obstruction. If you hit bare soil, your reading will be 0.

If there was mastication/chipping completed, record the depth of the chipped materials as well.

Fuel bed depth

Measure and record the height of the **tallest** downed and dead woody fuel for ten 5 ft collection point intervals (0-5 ft, 5-10 ft, 10-15 ft, up to 45-50 ft) along the planar transect. Measure from the **base of the litter layer to the top of the fuel particle**; measure to the nearest whole cm. If you do not have any dead and downed fuels, your measure will be based on the maximum litter depth in that interval.

Photos

Avoid people and gear in the photos. Line up with the photos supplied from previous plot visits to the best of your ability. Use a photo board to document the photo location within the photos, matching the plot naming protocol example above. **Always take the photos in a portrait orientation (up and down) with the transect tape in the bottom middle of the image**. Photos were only taken from 0 to 50 ft for each fuels transect (labeled F1, F2, etc.), from C to D (and A to B if applicable) for the shrub transect, and one general picture of the plot (this one will not have an old photo to match).

2001 detailed plot specifics

Shrub transects (50 m)

There are two perpendicular transects (AB and CD) for these plots. They **should** be contour and up/down slope, but they **might** be shifted.

Herb quadrats

There are 10 quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the **left hand side** looking from 0 to 50 m for both the AB and CD transects.

Seedlings

This is a circular plot starting at the pole/seedling origin rebar (at 33.92m on transect CD) extending out and around 3.99 m in all directions.

Pole-sized trees

This is a circular plot starting at the pole/seedling origin rebar (at 33.92m on transect CD) extending out and around 8.92 m in all directions.

Overstory trees

This is a circular plot starting from the origin (at 25 m on transect CD) extending out and around 17.85 m in all directions.

Canopy cover

A total of 100 canopy cover readings will be measured. They will start at 1m and continue every meter until the ends of each transect (50 m). This is to be done along **both** transect AB and CD.

Fuel loading

There are four 50 ft fuel transects for this layout. They start at 7.15 m and 42.85 m along the AB and CD transects extending out at a 45º angle. See the diagram for number convention and general layout.

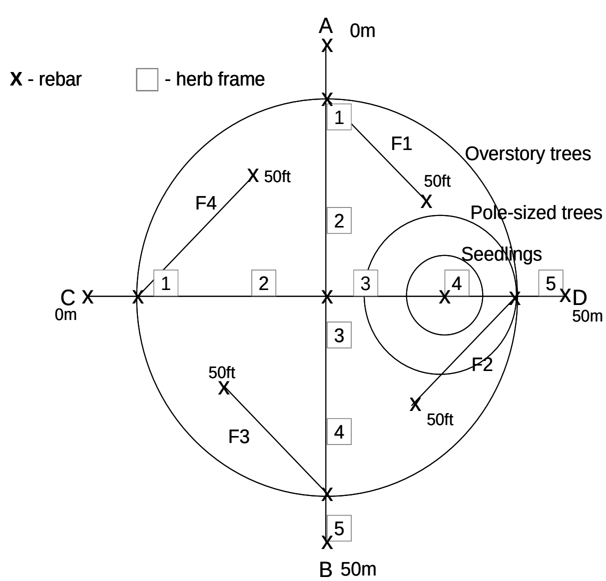


Figure 7. Plot layout diagram for the detailed plots installed in 2001 and 2002.