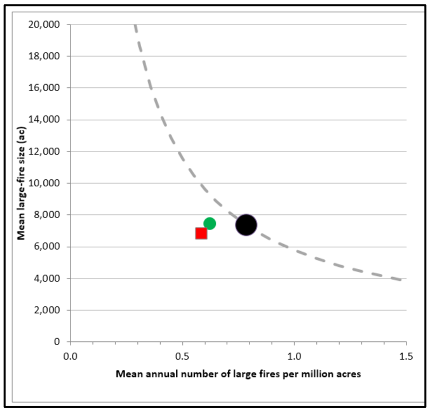
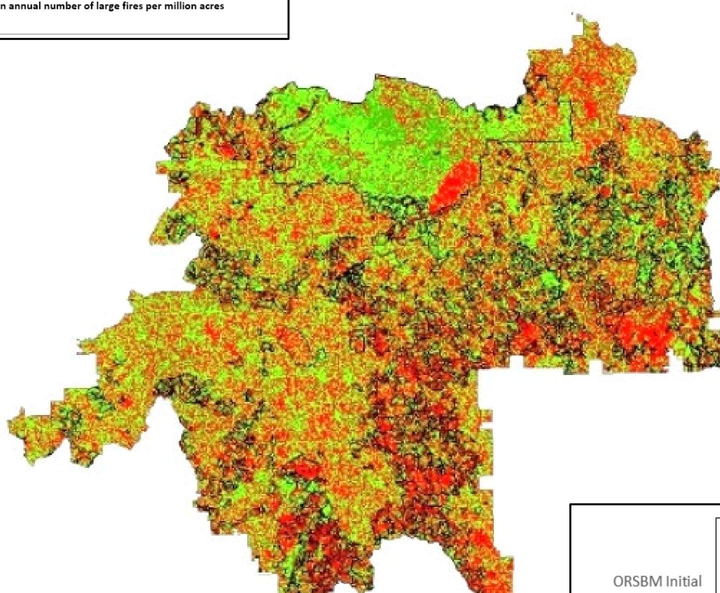
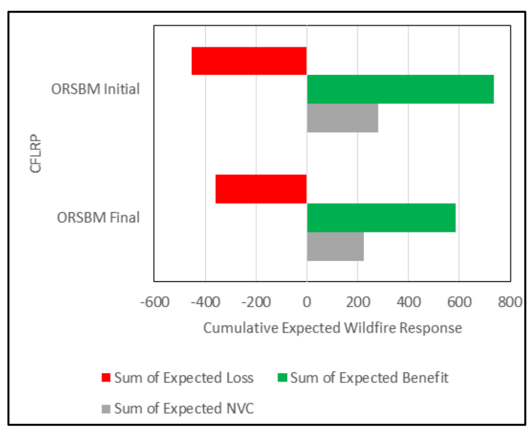
Wildfire Risk Index Pilot Project

A USDA Forest Service report from the Rocky Mountain Research Station, Fire Modeling Institute to the Collaborative Forest Landscape Restoration Program







DRAFT November 22, 2019

Table of Contents

Introduction

In 2017, the Forest Service completed a wildfire risk assessment for all National Forest System lands in the conterminous U.S. (Dillon, in press). This assessment was completed by the Fire Modeling Institute (FMI), which is an applied work group at the Missoula Fire Sciences Lab, part of the Forest Service's Rocky Mountain Research Station. The assessment was done at the direction of the Landscapes and Partnerships staff area of the Washington Office Fire and Aviation Management program. The intent of the assessment was to apply recent advancements in spatial wildfire modeling and quantification of wildfire risk from Forest Service research to help broadly articulate agency-wide perspectives on wildfire management and tie prioritization of hazardous fuels spending to a scientifically-based analysis (USDA OIG 2016).

A key outcome of the 2017 risk assessment was the introduction of a Wildfire Risk Index that the Forest Service could use to monitor performance toward the agency's broad objective of mitigating wildfire risk. Dillon (in press) proposed using a metric of "expected losses" as the basis for the index. This is one of several measures of wildfire risk calculated using a standard risk assessment framework (Scott et al. 2013). The 2017 assessment, based on 2012 landscape conditions, would be the baseline against which future calculations of the index could be compared. Dillon (in press) also acknowledged, however, that testing was needed to better understand the sensitivity of the proposed index and other measures of risk to different types of landscape change.

This report presents the results of the Wildfire Risk Index Pilot Project, an effort in coordination with the national Collaborative Forest Landscape Restoration Program (CFLRP) to test the risk index and other quantitative measures of wildfire hazard and risk. Five CFLRP project areas were selected to represent a diversity of ecosystems, as well as landscape-scale treatments and disturbances. FMI analysts performed wildfire simulations and risk calculations on both pre-treatment (2012) and post-treatment (2019) landscape conditions for these five areas. This report is structured as follows:

- A front section that provides a brief background on the wildfire risk assessment concepts, terminology, and datasets. Information about fuels mapping and wildfire simulation common to all five CFLRP areas is also presented here.
- A section for each of the five project areas describing specific considerations and results for the specific area.
- A closing section with some overall results comparing the five areas and conclusions from the pilot project as a whole.

Wildfire Risk Assessment Background

The approach used by FMI for the 2017 risk assessment builds on developments primarily from Forest Service research over the past fifteen years. Finney (2005) initially proposed an equation for quantifying wildfire risk based on the likelihood of fire occurrence, the likely intensity of fire if it occurs, and the effect of fire at different intensities on things of value. The LANDFIRE project then produced the type of fuels datasets needed to model wildfire consistently across the United States (www.landfire.gov), and wildfire simulation modeling tools were developed to estimate the probability of wildfire occurrence at different intensities (Finney et al. 2011). A first attempt at calculating wildfire risk nationally was published around 2010 (Calkin et al. 2010, Thompson et al. 2011), and a framework for doing a wildfire risk assessment was published in 2013 (Scott et al. 2013). The 2017 assessment represented an update to the 2010 assessment, incorporating many advancements in data, simulation modeling, and various elements of the risk assessment methods (Dillon, in press).

It is important to clarify that we are dealing here with risk in a strategic context that considers the potential effects of fire on things of value on the landscape, not with operational risks to firefighters. We use the following definition of wildfire risk: a measure of the probability and consequences of uncertain future wildfire events (Thompson et al. 2016). There are three fundamental components involved in a quantitative assessment of risk: 1) the likelihood of fire occurrence, 2) the potential intensity of wildfire if it occurs, and 3) the susceptibility of highly-valued resources and assets (HVRAs) to fire of different intensities.

The first two components of risk, likelihood and intensity, are derived through simulation modeling. The next two sections describe considerations for this pilot project around input data for modeling and the modeling itself.

Fuels Mapping Methods

Any fire modeling exercise is dependent on information about fuels in the analysis area. Models of fuel have been around as long as fire models themselves. However, the advent of spatially explicit fuel models, that are allowed to vary across a landscape, permitted the movement from point-based fire behavior modeling to spatial fire behavior modeling. Originally, spatial fuel models were often disparate and locally tuned. The development of LANDFIRE datasets has helped make fuels layers that are nationally consistent and provide for an update schedule to allow managers to deploy robust fuels information in their local or regional analysis.

In this analysis we used LANDFIRE fuels data layers to drive the large fire probability model FSim. Input layers were typical of most fire behavior models:

- Scott and Burgan (40) Fuel Models – Standard fire behavior fuel models.
- Canopy Cover – Percent cover of forest floor from vertically projected tree canopies.
- Canopy Height – Average height of the top of vegetated canopy.
- Canopy Bulk Density – The density of available canopy fuel in a stand.
- Canopy Base Height – Average height from ground to the bottom of a stand's canopy.
- Elevation – Meters above mean sea level.
- Slope – Change of elevation over a specified area.
- Aspect – Azimuth of sloped surface.

Additionally, LANDFIRE provides spatial data information on various physical and environmental parameters used to classify fuels. These layers were used in the "post" assessment to account for the effects of treatments and fire on existing fuel conditions and modify them, accordingly, to assess the changes in large fire probability. The layers used in the fuel change modeling were (with brief explanation):

- Biophysical Setting – Classification of vegetation that may have existed before Euro-American settlement.
- Existing Vegetation Type – Existing complexes of plant communities.
- Existing Vegetation Cover – A vertical projection of live percent canopy cover for an area.
- Existing Vegetation Height – Average height of existing vegetation.

Finally, a Fuel Disturbance (FDIST) layer, which is a spatial dataset that accounts for disturbance across the landscape, was created using existing LANDFIRE information, local area treatment information (typically from the FACTS database), and wildfire occurrence and severity. In areas where multiple treatments were spatially coincident, standard rules were used to assign a treatment type and severity. The fuel disturbance information is used, in conjunction with the physical and environmental information (above), to modify landscape fuel parameters (e.g. fuel model, canopy cover, etc.) and account for the changes that treatments have on the fuels in an area. The final product is an updated set up fuels characteristics that allow for a new set of fire modeling exercises to assess the treatment impact on fire risk.

Wildfire Simulation Methods: The Large-fire Simulation System (FSim)

The large-fire simulation system is an integrated model that accounts for fire occurrence, growth, and suppression to develop spatially explicit estimates of burn probability and intensity across a landscape for "large" fires. Since it is relatively rare for a large fire to occur in a given year, model simulations will span a large number of years, typically thousands, to develop the likelihood of a large fire occurring. Through this iterative process spatially specific probabilities of fire occurrence and the related intensities can be developed.

FSim is essentially composed of four modules – fire occurrence, fire growth and behavior, fire containment, and weather. The Weather module calculates, daily, whether the conditions will support a fire occurring. If a fire is supported by current conditions, the Occurrence module simulates the probability a fire will occur and grow to a "large" fire. The Growth module incorporates fuel information, weather, and topography to simulate daily growth of a fire. It includes flaming front spread and spotting. The containment module uses weather streams and user input to calculate if a fire will cease to grow. It contains a perimeter trimming algorithm to model progressive containment over time.

The first step in the modeling exercise (for each CFLRP) was calculating the average number of large fires per million acres *and* the average large fire size from the historic data of fire occurrence. These numbers are used to create a calibration target. The second step is model parameterization where outputs are compared to targets and adjustments made accordingly. Calibration simulations were run at a 1000-year time step (1000 yearly iterations of the model). Once the calibration outputs fell within a 70% confidence interval (calculated from the historic data), those parameters were used for initial (pre-treatment, 2012) simulation. The initial simulation time step was set to 10,000 years. The definition of a large fire was set to use a common standard, 100 hectares (247.1 acres), where any fire greater than or equal to 247.1 acres was counted as a large fire.

The final step of the modeling exercise was to incorporate the update fuels data and re-run FSim with the same parameters as the initial simulation. This ensures that the only changes in the final outputs are from the difference in fuel model characteristics, which represent the treatments and fires on the landscape.

In order to model fire at landscape scales, the area of interest (the CFLRP boundary, in this case) needs to be buffered by a certain amount in order to capture the spatial variation of fire occurrence and growth. All CFLRP boundaries were buffered by 20km and this area was used as the fire simulation analysis area. Final results, however, were clipped to CFLRP specific boundaries.

Risk Calculation Methods

As described above, the quantification of wildfire risk across a landscape involves three pieces of information: 1) wildfire likelihood; 2) wildfire intensity; and 3) susceptibility of highly-valued resources and assets (HVRAs) to wildfire of different intensities. We derive the first two of those from FSim modeling. For the third component, we need to define a list of HVRAs to include in the analysis. Because this pilot project is a test of risk metrics calculated for the 2017 national assessment, we chose to use the HVRAs as mapped and characterized for that assessment.

They HVRAs included in this analysis include the following five primary categories: 1) Communities, 2) Infrastructure, 3) Surface Drinking Water, 4) Ecosystem Function, and 5) Air Quality (table 1). Each of these represents something on the ground that is of value and could potentially be affected by wildfire (negatively or positively), and for which quality, nationally comprehensive and consistent GIS data exist. Because this pilot project is assessing much more local areas, we recognize that we may be excluding locally-important HVRAs. However, for the sake of this initial analysis we use the same set of national-consistent HVRAs. More details on these HVRAs are available online at: https://www.firelab.org/project/national-wildfire-risk-assessment.

To estimate the effect of fire on each HVRA, we use what are referred to as “response functions” (Scott et al. 2013). At each of six different fire intensity levels, we estimate how wildfire would change the value of a given resource or asset. We do this on a conceptual, non-monetary scale that ranges from +100 (effects are fully beneficial) to -100 (effects are fully negative; total loss) with zero being neutral. Response functions for each HVRA we used in this analysis are shown in table 1.

Another important step in characterizing the HVRAs is to determine how important each HVRA is relative to the others. This is used to weight each HVRA when calculating our final risk metrics that integrate the effect of fire across all of them. The process for doing this for the 2017 national risk assessment was fairly complex and involved engaging with agency leadership to rank HVRAs in terms of management priorities, factoring in the relative spatial extent of each HVRA, determining if importance varies by region, and ultimately calculating weighting factors. For this pilot project, we’re using the same relative importance characterizations used for the national assessment. Figure 1 shows essentially the relative contribution each of the five primary HVRAs contributed to final risk metrics in each Forest Service region.

Table 1: Highly Valued Resources and Assets included in the risk calculations.

Highly Valued Resources and Assets (HVRAs)		Response Function by Intensity (Flame Length)					
HVRA	**Sub-HVRA**	**FIL1 (0-2 ft)**	**FIL2 (2-4 ft)**	**FIL3 (4-6 ft)**	**FIL4 (6-8 ft)**	**FIL5 (8-12 ft)**	**FIL6 (12+ ft)**
Communities		-10	-20	-40	-60	-80	-90
Surface Drinking Water		0	0	-20	-35	-50	-65
Infrastructure	Powerlines	0	0	0	-30	-40	-50
	Communication Sites	0	0	-10	-30	-40	-50
	Buildings and Developed Rec Sites	-10	-20	-40	-60	-80	-90
Ecosystem Function	Fully positive	100	100	100	100	100	100
	All positive, decreasing slightly	100	100	100	90	80	70
	All positive, undulating	100	80	80	50	60	70
	Fully positive to neutral	100	100	80	50	20	0
	Moderately positive to fully positive	50	80	100	100	100	100
	Fully positive to moderately negative	100	100	50	10	-20	-50
	Fully positive to strongly negative	100	100	50	-10	-50	-70
	Neutral	0	0	0	0	0	0
	Neutral to slightly negative	0	0	0	0	-20	-50
	Neutral to moderately negative	0	0	-10	-30	-40	-50
	Neutral to moderately negative2	0	-10	-10	-30	-40	-50
	All negative, decreasing	-50	-60	-70	-80	-90	-100
	Fully negative	-100	-100	-100	-100	-100	-100
Air Quality (Potential PM2.5 Emissions)	low	0	0	-10	-10	-10	-10
	moderate	-10	-10	-20	-20	-40	-40
	high	-30	-40	-50	-60	-80	-100

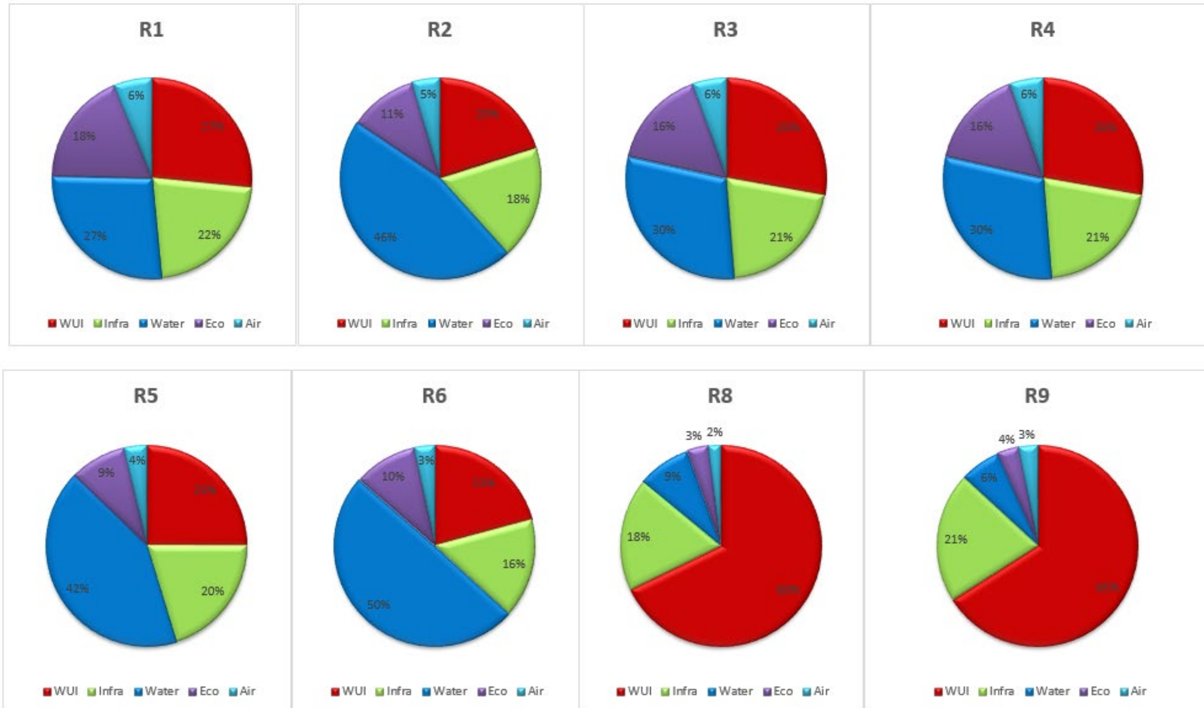


Figure 2: Relative Importance of each of the five primary HVRAs by Forest Service region. HVRAs are: red = communities; green = infrastructure; blue = surface drinking water; purple = ecosystem function; teal = air quality.

With information on the three components of risk, we can calculate wildfire risk to the identified HVRAs. Expected Net Value Change (eNVC) is the primary integrated measure of risk that incorporates the likelihood of fire, the probable intensities, and susceptibility of the HVRAs at each intensity. Where eNVC is negative, it represents an area where the outcome of a fire would likely be negative, expressed as loss of value to the HVRAs. Where eNVC is positive, it represents a positive net effect of fire. Because the positives and negatives for any given pixel on the landscape can offset each other, it can also be valuable to view the Expected Losses and Expected Benefits separately. We calculate each of these metrics in a raster GIS environment, where calculations are done for each pixel and then can be aggregated for an analysis area as the sum or the mean for the area.

Currently, we have proposed using the Expected Losses metric as a wildfire risk index that the Forest Service can use to track progress over time toward the strategic goal of “mitigating wildfire risk” (Dillon, in press). For each of the five CFLRP project areas included in this analysis, we report sum of Expected Losses, Expected Benefits, and Expected Net Value Change because we want to better understand how each is affected by different types of landscape change. We also report the average burn probability and expected annual area burned (which is average burn probability times total area size).

Southwest Jemez Mountains

The Southwest Jemez Mountains CFLRP is composed of approximately 210,000 acres in northwest New Mexico (figure 1.1). It includes 110,000 acres of the Sante Fe National Forest, the 86,000-acre Valles Caldera National Preserve, the Pueblo of Jemez, and various State, Private, and Tribal lands. The analysis area, based on a 20 km buffer of the CFLRP boundary, is approximately 1,158,900 acres. Data from the Jemez RAWS was used to develop the weather stream for simulations.

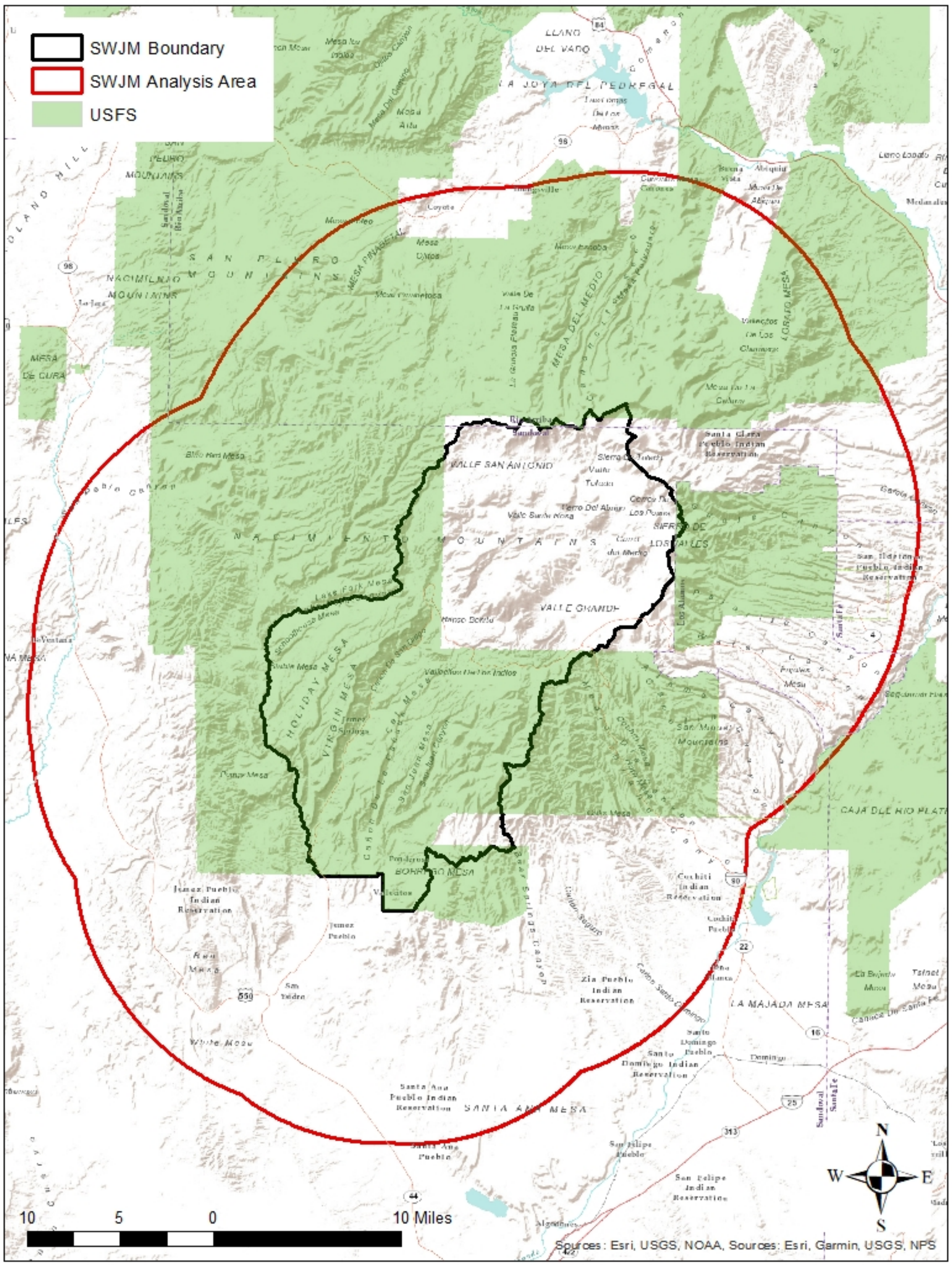


Figure 1.1: Southwest Jemez Mountains CFLRP boundary and analysis area.

During the analysis period from 2012 to 2019, approximately 83,200 acres within the Southwest Jemez Mountains project area experience some type of treatment or disturbance. This included 76,838 acres of fire (37% of project area); 1,245 acres of mechanical add treatments (<1%); 3,879 acres of mechanical remove treatments (2%); and 1,257 acres affected by exotics (<1%). For the Fuel Disturbance information used to modify fuels data for the post-treatment FSim modeling, these categories were subdivided by severity (low, medium, high), and years since disturbance (1, 2-5, 6-10). In areas with overlying treatment polygons, standard rules were employed to categorize the treatment: fire takes precedence over mechanical add which takes precedence over mechanical remove, and so on through the disturbance codes. Similarly, more recent activities take precedence over earlier activities. The acreage by disturbance type and severity are shown in figure 1.2.

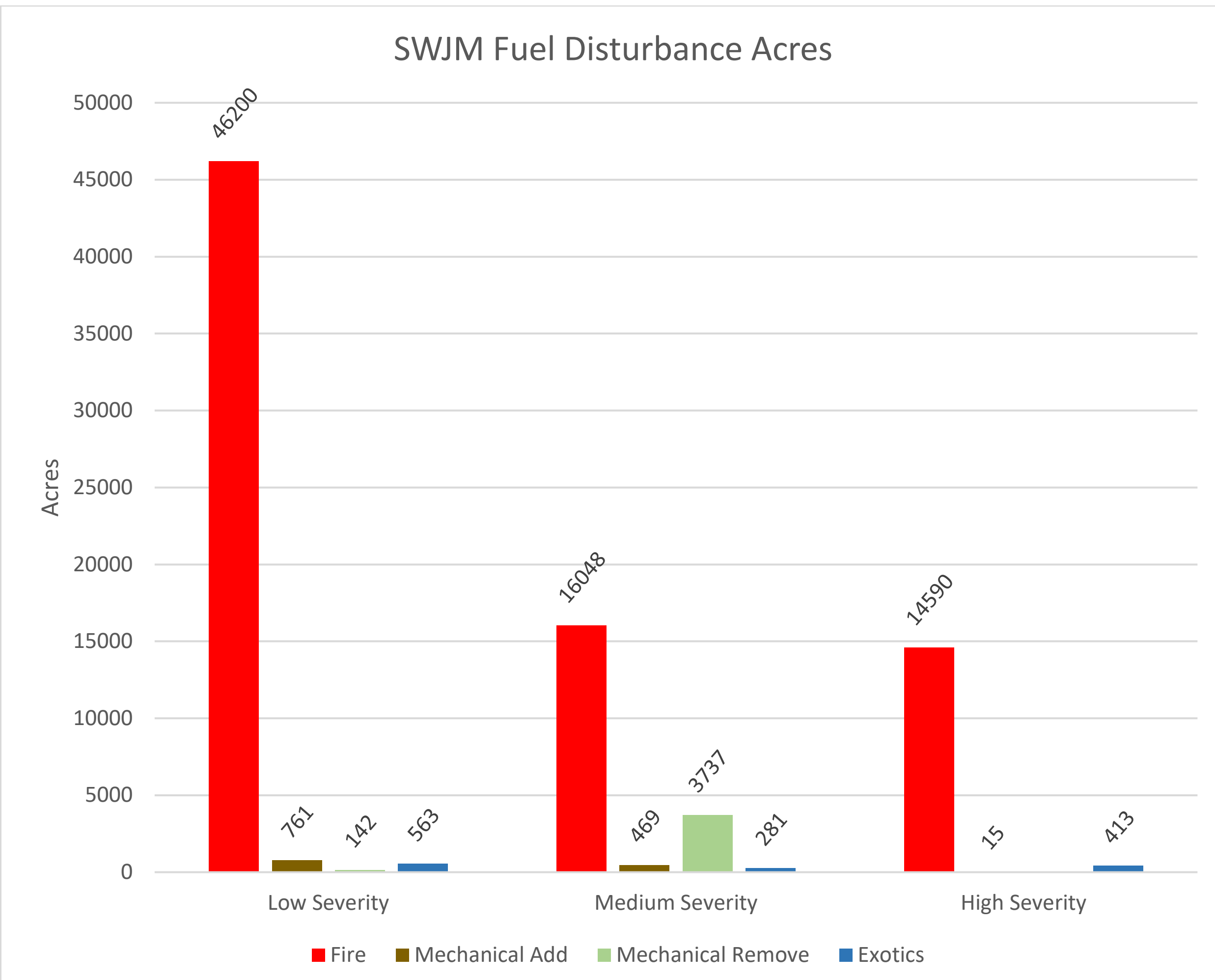


Figure 1.1: Acres of landscape disturbance and treatements by disturbance type and severity for the Southwest Jemez Mountains CFLRP project area.

The FSim calibration plot for the SWJM shows the calibration target and results of the initial and post-treatment modeling with respect to the average number of large fires and the average large fire size (figure 1.3). Using the pre-treatment landscape, we did calibration runs of FSim, adjusting input parameters until we fell within the 70% confidence interval of the historic target. Once we met this criterion, we ran final simulation for initial conditions using 10,000 model iterations. After modifying the landscape fuels to account for fire occurrence and treatments, we ran the post-treatment simulation with the same time-step and model parameterization as the initial run. Interestingly, the post-treatment simulation results showed a slight increase in both the mean annual number of large fires per million acres (shown on the X axis) and the mean large fire size.

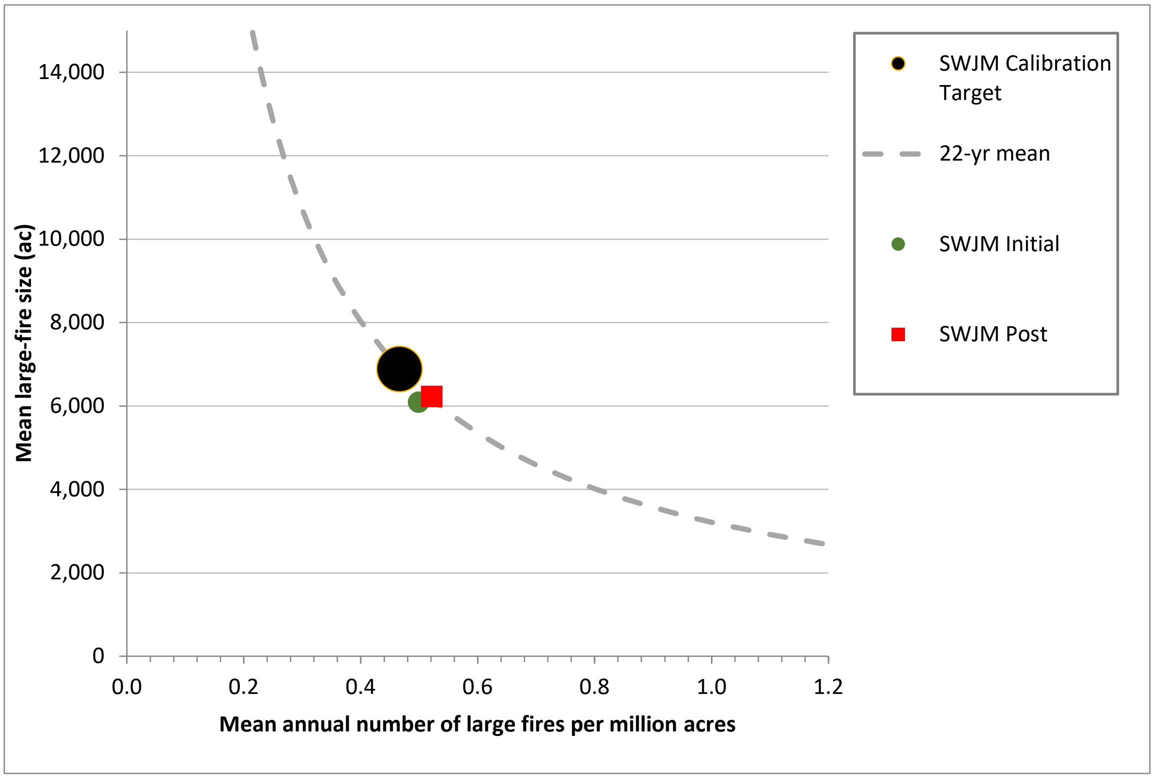


Figure 1.3: Calibration table for Southwest Jemez Mountains.

Summary statistics for select FSim outputs and risk metrics are shown in table 1.1. The change in each metric from 2012 to 2019 is shown as a percentage, relative to the initial value. Positive change numbers show an increase after treatment (the number moved further away from zero), while negative numbers show a decrease (moving toward zero). Given the general goal of reducing risk from wildfire while increasing the likelihood of beneficial outcomes, these numbers can be interpreted as follows:

- Decreases in burn probability and expected annual area burned are generally desirable will contribute to reduced risk.
- Decrease in intensity will also contribute to reduced risk.
- If the sum of expected loss (the proposed risk index) move closer to zero, this represents a reduction of risk.

- If the sum of expected benefit increases, this represents a higher likelihood of beneficial outcomes.
- If the sum of expected NVC increases (gets more positive), this represents either a reduction of risk or increase in potential benefit (or both). If the sum of expected NVC decreases (gets more negative), this represents either an increase in risk or decrease in potential benefit (or both).

Table 1.3: Zonal Statistics for Southwest Jemez Mountains.

	Acres	Average Burn Probability	Expected Annual Area Burned	Sum of Expected Loss (Risk Index)	Sum of Expected Benefit	Sum of Expected NVC
SWJM 2012	210,654	0.004946	1041	-139	256	117
SWJM 2019	210,654	0.004677	985	-148	256	109
Percent Change		-5.4%	-5.4%	6.3%	0.1%	-7.3%

As expected, the results for the SWJM project area are complex and require some explanation and interpretation. Average burn probability decreased in 2019, with a corresponding decrease in annual expected area burned (which is total project area acres x burn probability). Conversely, the proposed risk index, Sum of Expected Loss, increased slightly, while the Sum of Expected Benefit remained static.

The changes in expected NVC and its component pieces of expected loss and expected benefit can also be viewed graphically (figure 1.4). The overall expected benefit of fire stayed consistent between the initial and post assessments, but the Sum of Expected Net Value Change (which is the sum of benefit and loss) decreased in the final assessment. This was driven by the final assessment increase in Expected Loss. The Sum of Expected NVC remains positive in both assessments and reflects the notion that fire, generally, shows positive impacts on the Highly Valued Resources and Assets (HVRA) used in the exercise.

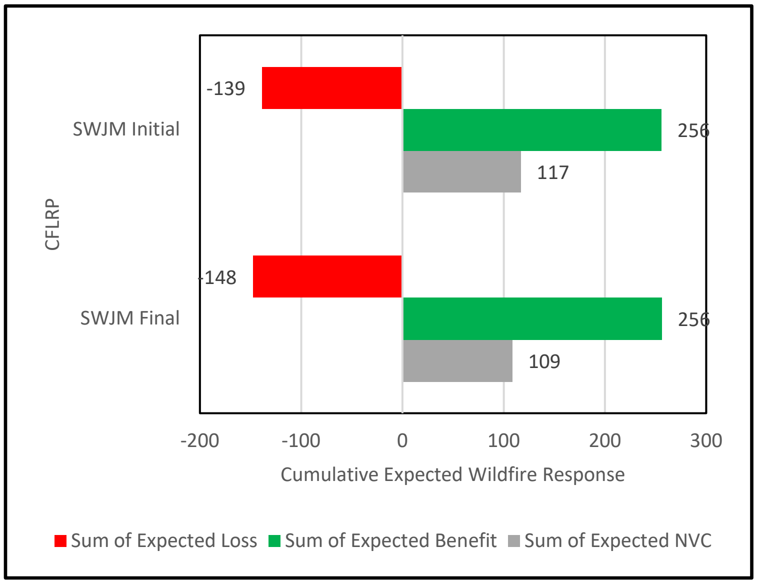


Figure 1.4: Cumulative Expected Wildfire Response for the Southwest

Looking directly at the estimate of wildfire likelihood and intensity from FSim can also help to understand how landscape changes affected expected fire behavior. As shown in table 1.1, burn probability decreased slightly from 2012 to 2019 overall, but changes in probability varied across the project area (figure 1.5). Generally, increases and decreases in burn probability were moderate. Major increases or decreases in burn probability were limited spatially to relatively small patches.

Intensity outputs from FSim are categorized into Fire Intensity Level (FIL) classes, which are described by flame lengths. For each pixel, FSim gives us the conditional probability for each FIL class. In other words, if a fire occurs, what are the chances of seeing each of six flame length classes? Probabilities for each pixel sum to one. These six FIL classes are:

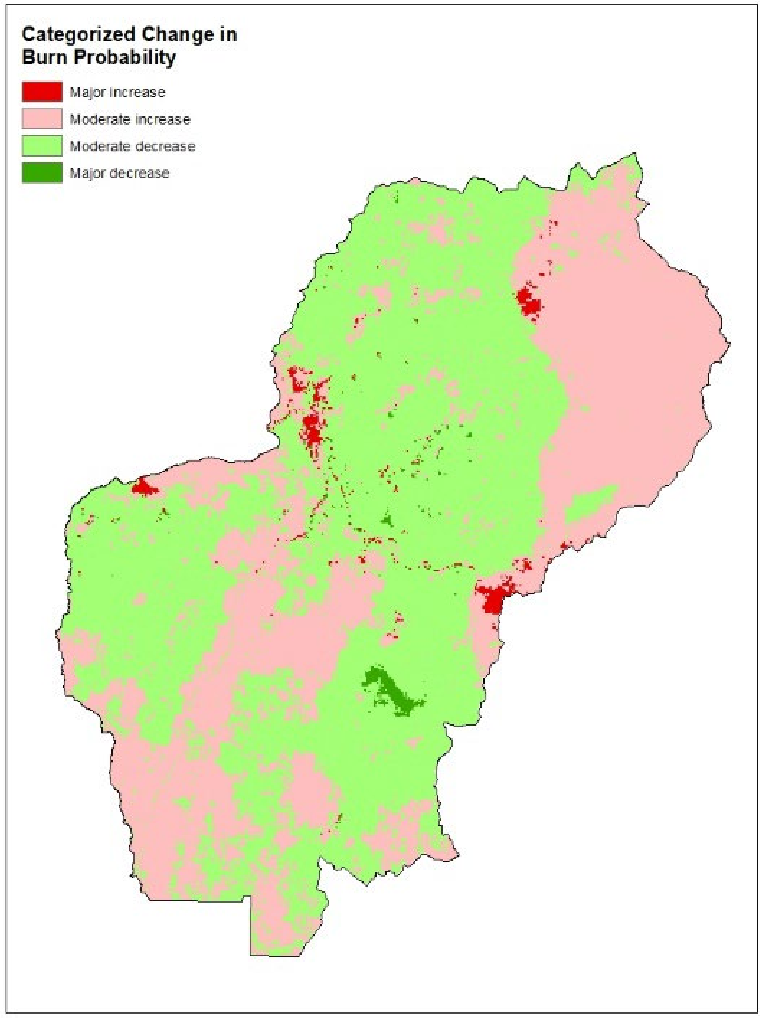


Figure 1.5: Difference in Burn Probability for the Southwest Jemez Mountains CFLRP. Areas shown in green have decreased likelihood of wildfire in the post-treatment landscape, while areas in red have increased likelihood of wildfire.

Class	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6
Flame length (ft)	0-2	2-4	4-6	6-8	8-12	12+

Flame Length Exceedance Probability (FLEP) is a measure that aggregates the FIL probabilities to make interpretation easier. FLEP is the probability a given pixel will experience a flame length equal to or greater than a certain value. It is calculated by simply summing the probabilities for FIL classes above a flame length of interest. For example, FLEP6 is the probability that a pixel will experience flame length greater than 6 feet and is the sum of probabilities for FIL 4, FIL 5, and FIL 6 (FIL 4 being 6-8 feet). FLEP8 is similar but is the probability of experiencing 8-foot flame lengths or greater and is the sum of probabilities for FIL 5 and FIL 6.

We calculated FLEP6 and FLEP8 for initial and post-treatment conditions (table 1.2, figure 1.6). We spilt our calculations in to two categories. The first is for the entire CFLRP project area, while the second is calculated only for “treated” areas. The treated areas correspond to the final Fuel Disturbance layer (FDIST) used in modifying LANDFIRE fuels for the 2019 assessment. These include all treatments and fires.

Across the entire project area, changes in FLEP6 and FLEP8 were very slight, with minor increase in FLEP6 and an even smaller decrease in FLEP8 (table 1.2, figure 1.6). When looking only at “treated” areas, we observed a more substantial change in both FLEP classes. In the post-treatment landscape by FLEP6 was reduced by 11.6%, while FLEP8 was reduced by 22.9%, relative to the 2012 landscape.

Table 1.4: Mean flame Length Exceedance Probabilities (FLEP6 and FLEP8) for entire project area and “treated” areas only. Negative Percent Change indicates a decrease in the probability post-treatment.

		Entire Project Area		Treatment Areas Only (FACTS and FIRE)	
		Mean	Percent Change	Mean	Percent Change
FLEP6	Initial	0.3885		0.2971	
	Post	0.3914	0.8%	0.2627	-11.6%
FLEP8	Initial	0.2443		0.1862	
	Post	0.2435	-0.3%	0.1435	-22.9%

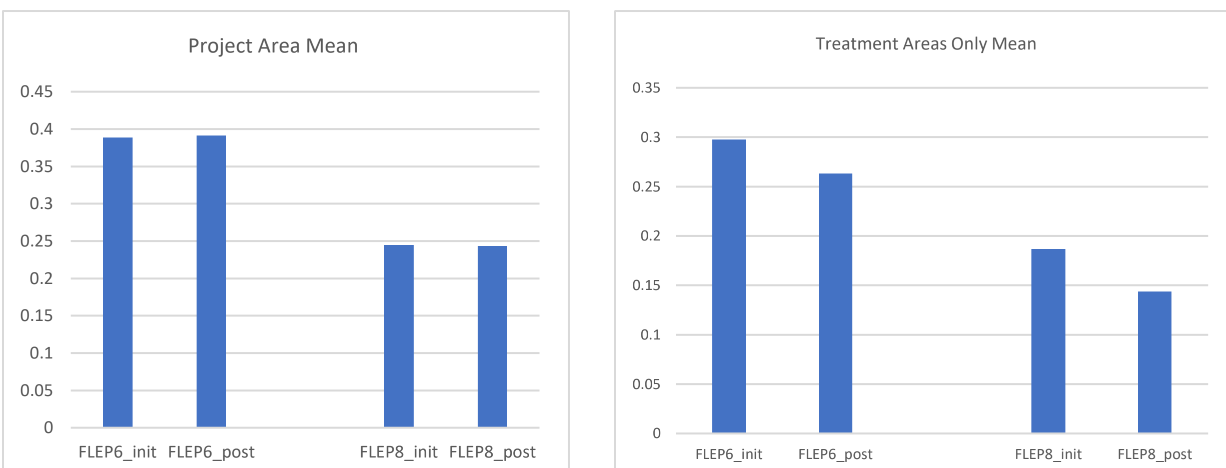


Figure 1.6: FLEP6 and FLEP8 probabilities for CFLRP boundary and treatment specific areas.

As with burn probability, changes in expected wildfire intensity between 2012 and 2019 were spatially variable (figure 1.7). In general, the areas with major increase in FLEP6 and FLEP8 are outside of treated areas. Decreases in FLEP6 and FLEP8 occurred across the project area, but concentrations of major decrease are found within treatment areas.

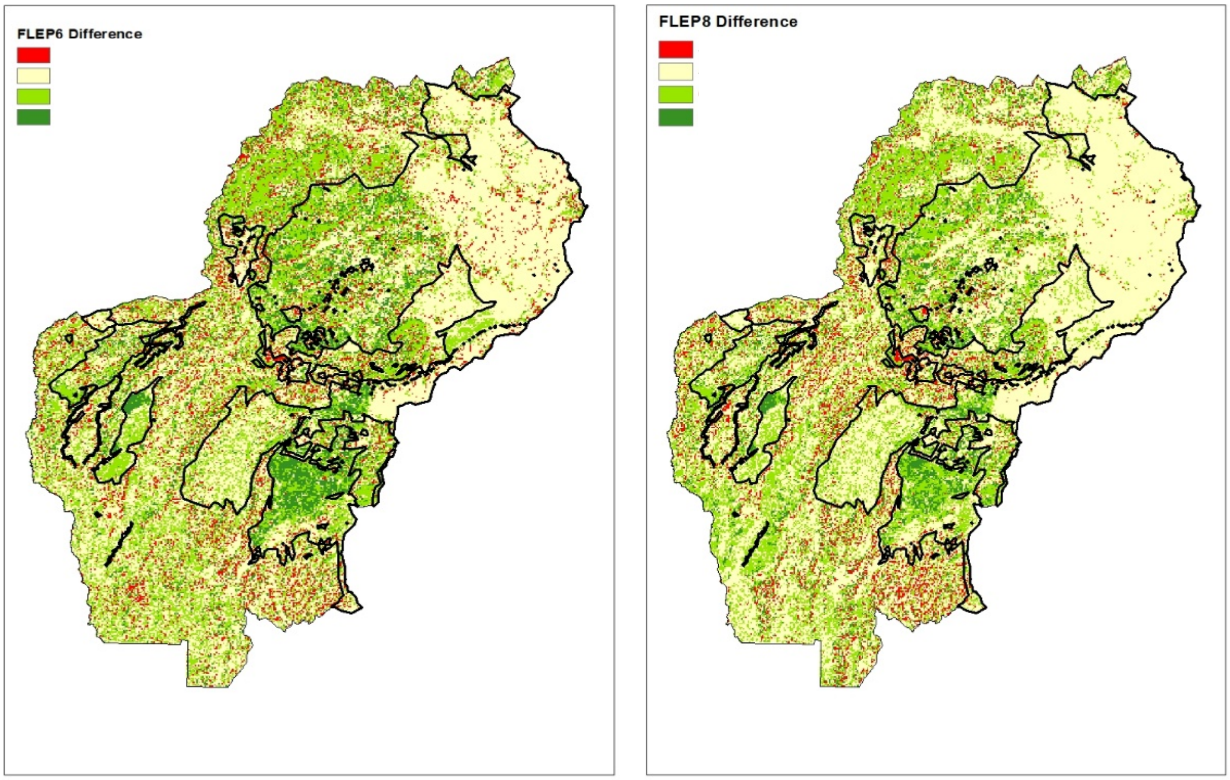


Figure 1.7: Difference of FLEP 6 and FLEP8. Positive numbers indicate and improvement in Final FLEP probabilities. Polygons represent fire and treatment areas.

Discussion – Southwest Jemez Mountains

Overall, the results indicate a general improvement in fire hazard in the Southwest Jemez Mountains. While the proposed risk index (sum of expected loss) became more negative indicating a slight increase in risk, the combination of other indicators suggests a general improvement. The mean burn probabilities and expected annual area burned both decreased in the final assessment. This indicates fewer fires that are smaller in size are expected from the simulations. Additionally, Flame Length Exceedance Probabilities (FLEP), the likelihood of a pixel experiencing a given flame length, decreased in treated areas which indicates the treatments are successful in moderating predicted fire behavior. Finally, the sum of expected NVC remains positive, indicating an overall positive impact of fire on HVRAs used in the analysis.

While these results may seem contradictory, they are, generally positive. On the whole, fire occurrence is expected to be have lower negative impact and a greater benefit on the HVRAs evaluated. The Southwest Jemez Mountains poses an interesting case in that it experienced two very large fires (Las Conchas in 2011 and Thompson Ridge in 2013) that appear to have impacted the assessment. Subsequent analysis is worth exploring the contribution these fires had on the results presented here. The results of this analysis are sensitive to the HVRAs included and the way that effects were quantified with response functions. We used consistent HVRAs and parameters in this pilot project for the purpose of testing and consistency, but future work could explore local adjustments to fine-tune results for the SWJM project area.

Oregon Southern Blue Mountains

The Southern Blue Mountains CFLRP of eastern Oregon is made up of approximately 1,035,000 acres, a significant portion of which is Malheur National Forest lands. The analysis area, a 20 km buffer of the CFLRP boundary, consists of more than 3.5 million acres (figure 2.1). The Falls Creek RAWS data were used to generate weather streams for the simulations.

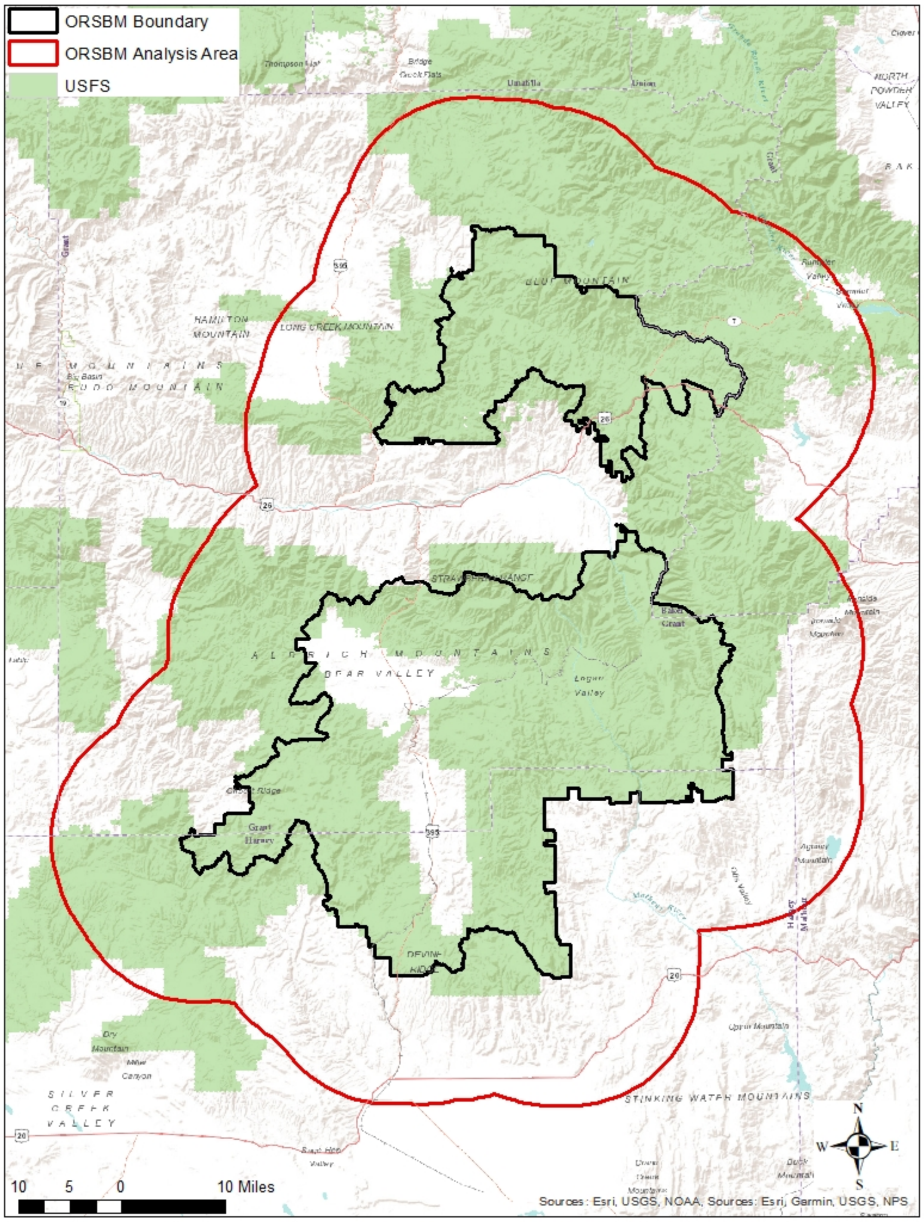


Figure 2.1: Oregon Southern Blue Mountains CFLRP boundary and analysis area.

During the analysis period from 2012 to 2019, approximately 32,390 acres within the Oregon Southern Blue Mountains project area experience some type of treatment or disturbance. This included 18,400 acres of fire (2% of project area); 7,455 acres of mechanical add treatments (<1%); and 6,530 acres of mechanical remove treatments (<1%). For the Fuel Disturbance information used to modify fuels data for the post-treatment FSim modeling, these categories were subdivided by severity (low, medium, high), and years since disturbance (1, 2-5, 6-10). In areas with overlying treatment polygons, standard rules were employed to categorize the treatment: fire takes precedence over mechanical add which takes precedence over mechanical remove. Similarly, more recent activities take precedence over earlier activities. The acreage by disturbance type and severity are shown in figure 2.2.

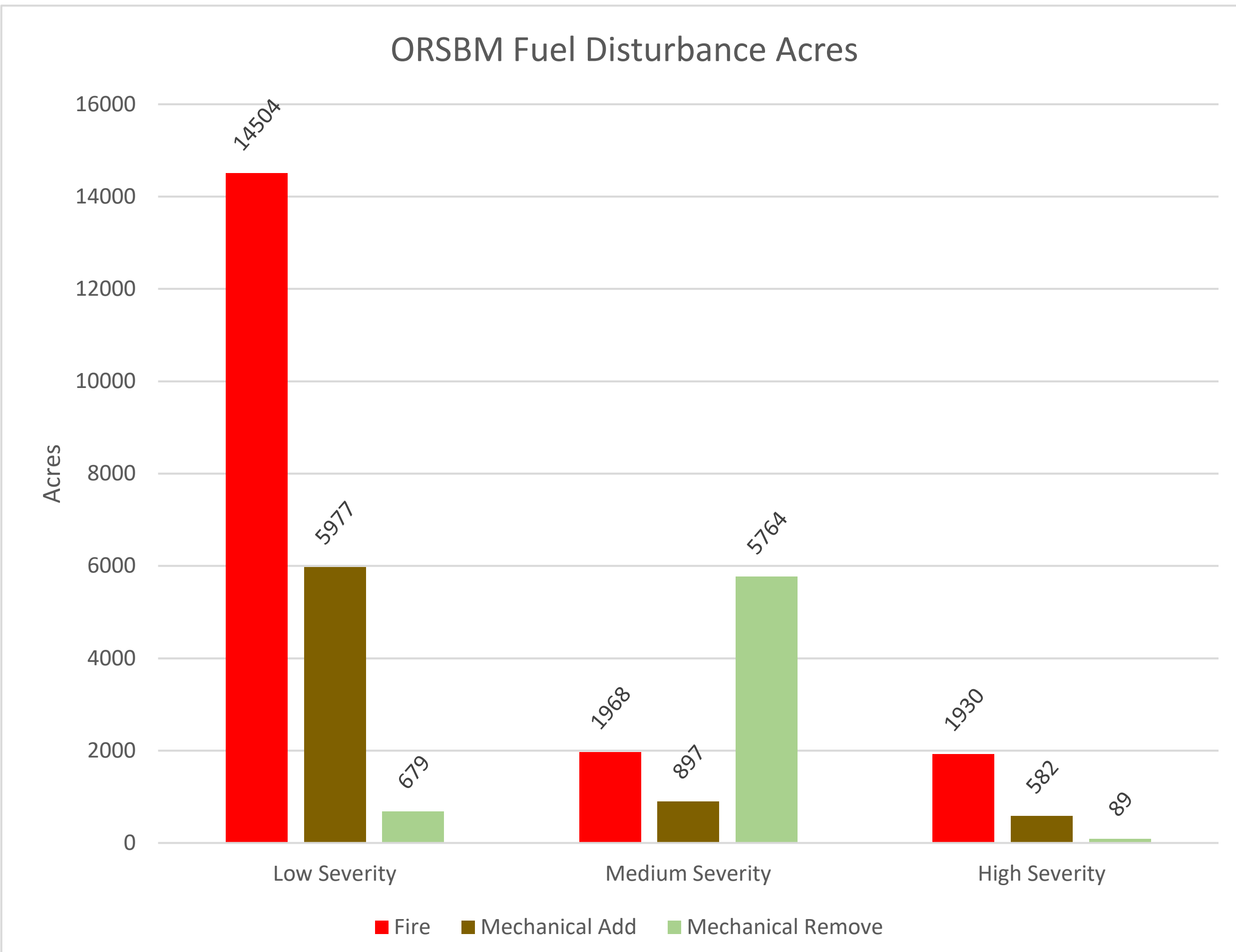


Figure 2.3: Acres of landscape disturbance and treatements by disturbance type and severity for Northeast Washington Forest Vision CFLRP project area.

The FSim calibration plot for the ORSBM shows the calibration target and results of the initial and post-treatment modeling with respect to the average number of large fires and the average large fire size (figure 2.3). Using the pre-treatment landscape, we did calibration runs of FSim, adjusting input parameters until we fell within the 70% confidence interval of the historic target. Once we met this criterion, we ran final simulation for initial conditions using 10,000 model iterations. After modifying the landscape fuels to account for fire occurrence and treatments, we ran the post-treatment simulation with the same time-step and model parameterization as the initial run.

The calibration plot in figure 2.3 shows the initial simulation was slightly lower in the mean number of fires per million acres than the calibration target. Average large fire size, however, was equivalent to the calibration target. The post-treatment simulations showed that both mean fire size and the number of large fires per million acres decreased.

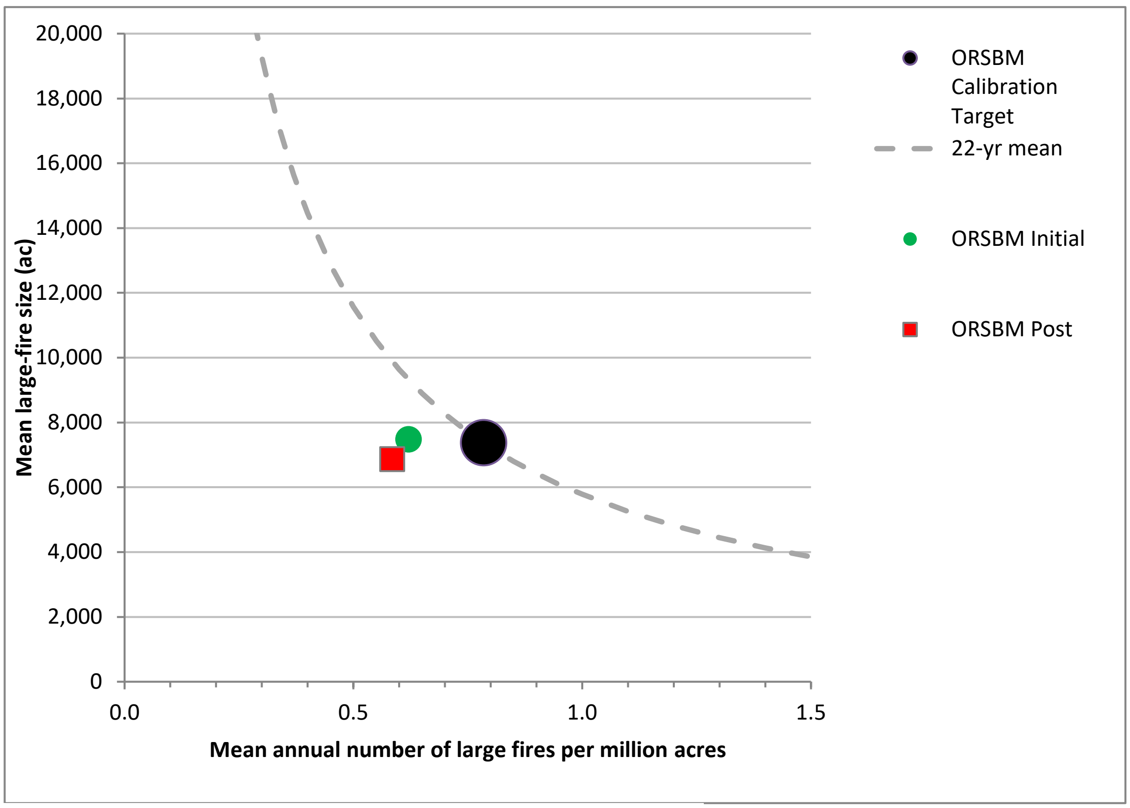


Figure 2.3: Calibration plot for Oregon Southern Blue Mountains.

Summary statistics for select FSim outputs and risk metrics are shown in table 2.1. The change in each metric from 2012 to 2019 is shown as a percentage, relative to the initial value. Positive change numbers show an increase after treatment (the number moved further away from zero), while negative numbers show a decrease (moving toward zero). Given the general goal of reducing risk from wildfire while increasing the likelihood of beneficial outcomes, these numbers can be interpreted as follows:

- Decreases in burn probability and expected annual area burned are generally desirable will contribute to reduced risk.

- Decrease in intensity will also contribute to reduced risk.
- If the sum of expected loss (the proposed risk index) move closer to zero, this represents a reduction of risk.
- If the sum of expected benefit increases, this represents a higher likelihood of beneficial outcomes.
- If the sum of expected NVC increases (gets more positive), this represents either a reduction of risk or increase in potential benefit (or both). If the sum of expected NVC decreases (gets more negative), this represents either an increase in risk or decrease in potential benefit (or both).

Table 2.5: Zonal Statistics for Oregon Southern Blue Mountains.

	Acres	Average Burn Probability	Expected Annual Area Burned	Sum of Expected Loss (Risk Index)	Sum of Expected Benefit	Sum of Expected NVC
ORSBM 2012	1,035,192	0.00355	3,674	-454	735	281
ORSBM 2019	1,035,192	0.002737	2,833	-361	585	224
Percent Change		-22.9%	-22.9%	-20.6%	-20.5%	-20.3%

As shown in table 2.1 and subsequent figures, most metrics of wildfire likelihood, area burned, and risk decreased between 2012 and 2019. Average burn probability, and correspondingly expected annual area burned (which is total project area acres x burn probability) both decreased by over 20 percent. The proposed risk index (sum of expected loss) also decreased, moving closer to zero and indicating a reduction in wildfire risk. The similar amount of decrease in the sum of expected benefit, however, slightly counteracts the decrease in expected loss, impacting the sum of expected NVC and making it slightly less positive in the post-treatment landscape. The relationship between expected NVC and its component pieces of expected loss and expected benefit can also be viewed graphically in figure 2.4.

Overall, the sum of expected NVC remains positive in the 2019 landscape and indicates an overall positive impact of fire on the Highly Valued Resources and Assets (HVRA) used in the analysis.

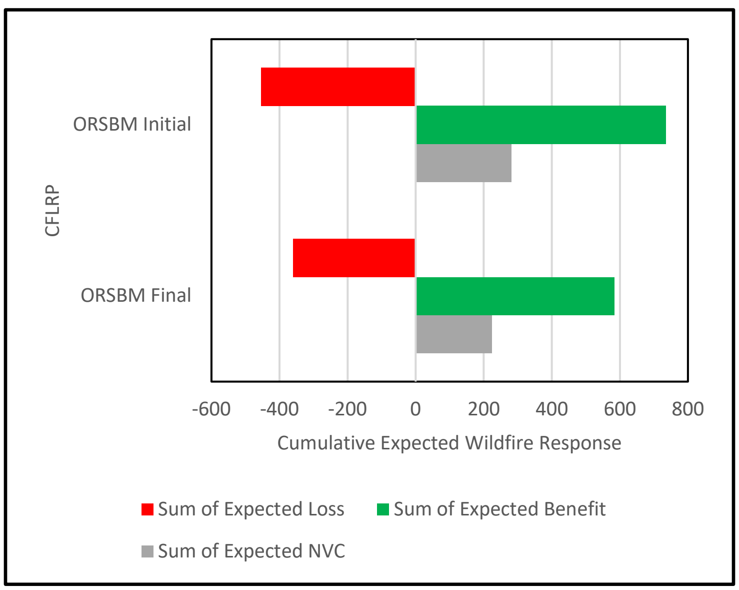


Figure 2.4: Cumulative Expected Wildfire Response for the Oregon Southern Blue Mountains CFLRP.

Looking directly at the estimates of wildfire likelihood and intensity from FSim can also help to understand how landscape changes affected expected fire behavior. As shown in table 2.1, burn probability decreased from 2012 to 2019 overall, but changes in probability varied across the project area (figure 2.5). Generally, increases and decreases in burn probability were moderate.

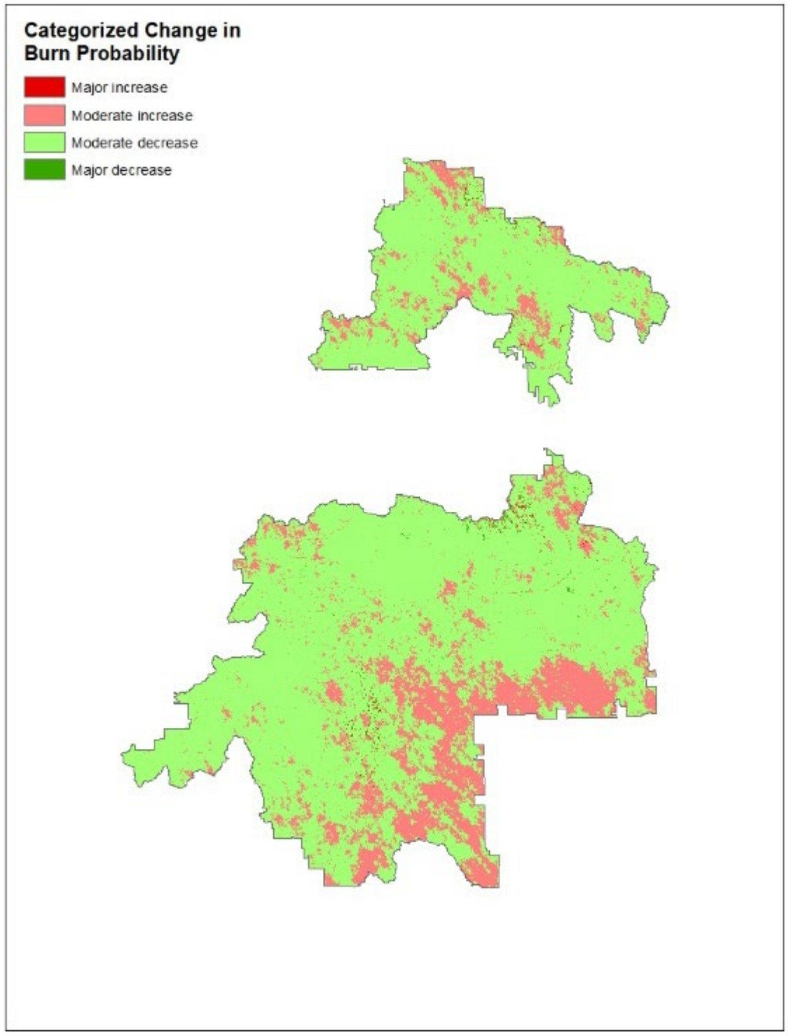


Figure 2.5: Difference in Burn Probability for the Oregon Southern Blue Mountains CFLRP. Areas shown in green have decreased likelihood of wildfire in the post-treatment landscape, while areas in red have increased likelihood

Intensity outputs from FSim are categorized into Fire Intensity Level (FIL) classes, which are described by flame lengths. For each pixel, FSim gives us the conditional probability for each FIL class. In other words, if a fire occurs, what are the chances of seeing each of six flame length classes? Probabilities for each pixel sum to one. These six FIL classes are:

Class	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6
Flame length (ft)	0-2	2-4	4-6	6-8	8-12	12+

Flame Length Exceedance Probability (FLEP) is a measure that aggregates the FIL probabilities to make interpretation easier. FLEP is the probability a given pixel will experience a flame length equal to or greater than a certain value. It is calculated by simply summing the probabilities for FIL classes above a flame length of interest. For example, FLEP6 is the probability that a pixel will experience flame length greater than 6 feet and is the sum of probabilities for FIL 4, FIL 5, and FIL 6 (FIL 4 being 6-8 feet). FLEP8 is similar but is the probability of experiencing 8-foot flame lengths or greater and is the sum of probabilities for FIL 5 and FIL 6.

We calculated FLEP6 and FLEP8 for initial and post-treatment conditions (table 2.2, figure 2.6). We spilt our calculations in to two categories. The first is for the entire CFLRP project area, while the second is calculated only for “treated” areas. The treated areas correspond to the final Fuel Disturbance layer (FDIST) used in modifying LANDFIRE fuels for the 2019 assessment. These include all treatments and fires.

Across the entire project area, FLEP6 and FLEP8 both showed a moderate decrease (table 2.2, figure 2.6). When looking only at “treated” areas, we observed a more substantial change in both FLEP classes. In the post-treatment landscape by FLEP6 was reduced by 27.2%, while FLEP8 was reduced by 31.9%, relative to the 2012 landscape.

Table 2.6: Mean flame Length Exceedance Probabilities (FLEP6 and FLEP8) for entire project area and “treated” areas only. Negative Percent Change indicates a decrease in the probability post-treatment.

		Entire Project Area		Treatment Areas Only (FACTS and FIRE)	
		Mean	Percent Change	Mean	Percent Change
FLEP6	Initial	0.4696		0.4250	
	Post	0.4361	-7.1%	0.3096	-27.2%
FLEP8	Initial	0.2990		0.2772	
	Post	0.2796	-6.5%	0.1889	-31.9%

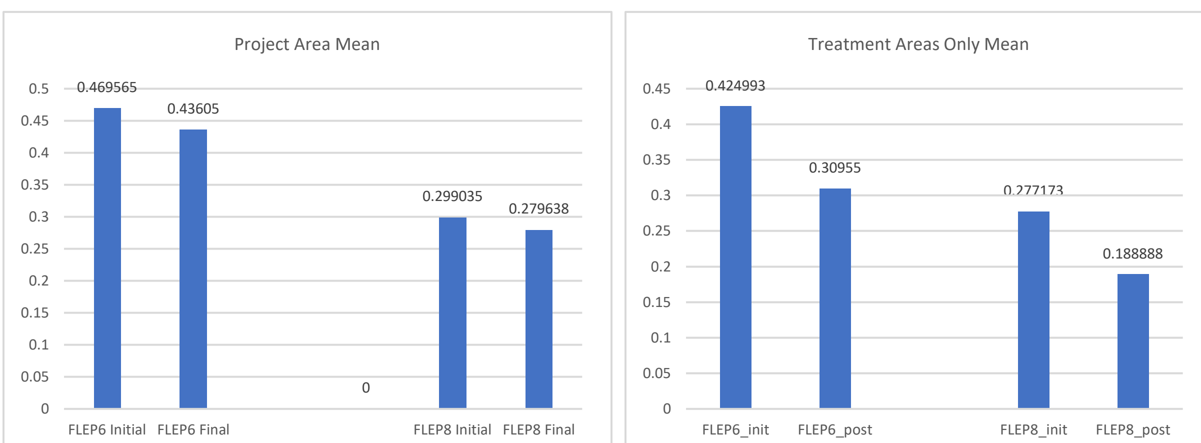


Figure 2.6: FLEP6 and FLEP8 probabilities for CFLRP boundary and treatment specific areas.

As with burn probability, changes in expected wildfire intensity between 2012 and 2019 were spatially variable (figure 2.7). In general, the areas with major increase in FLEP6 and FLEP8 are outside of treated areas. Decreases in FLEP6 and FLEP8 occurred across the project area, but concentrations of decrease in

FLEP are found within the treatment areas. As discussed above, both FLEP6 and FLEP8 decreased markedly in treated areas.

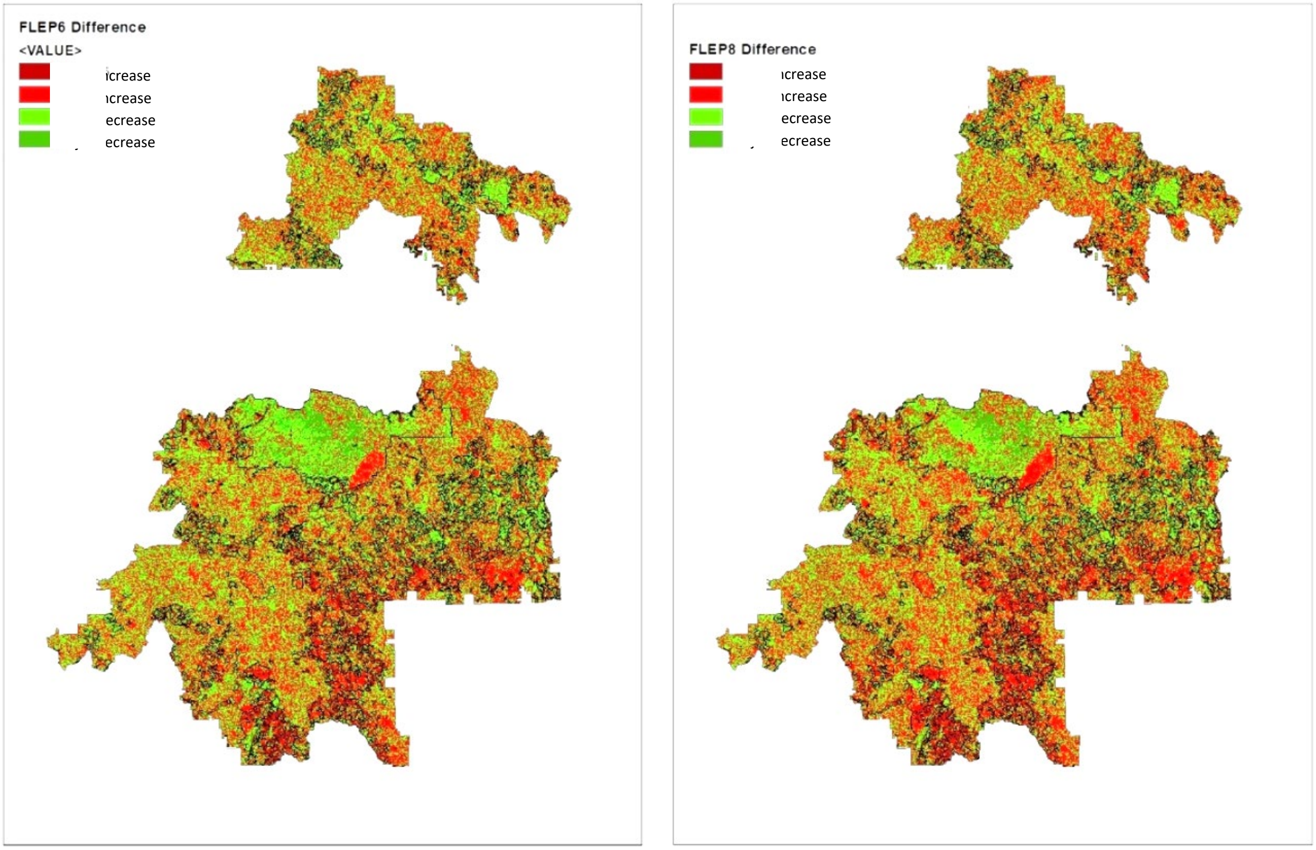


Figure 2.7: Difference of FLEP 6 and FLEP8. Positive numbers indicate and improvement in Final FLEP probabilities. Polygons represent fire and treatment areas.

Discussion – Oregon Southern Blue Mountains

Based on simulation data, the Oregon Southern Blue Mountains is experiencing a general decrease in expected fire impacts over the analysis period. Final simulations indicate a move to slightly lower mean annual number of large fire per million acres and a decrease in mean large fire size. The average burn probability and expected annual area burned both decreased by nearly 23%, while the proposed risk index (sum of expected loss) also fell by nearly 21%. The FLEP classes decreased moderately for the whole CFLRP and dropped markedly for the treated areas, approximately 27% and 32% for FLEP6 and FLEP8, respectively. While sum of expected benefit also dropped, indicating less benefit from fire in the post-treatment landscape, the sum of expected NVC remains positive (slightly less in 2019 due to the expected benefit change) and indicates an overall positive expected impact of fire on the landscape.

Overall, the results of this analysis are sensitive to the HVRAs included and the way that effects were quantified with response functions. We used consistent HVRAs and parameters in this pilot project for the purpose of testing and consistency, but future work could explore local adjustments to fine-tune results for the ORSBM project area.

Northeast Washington Forest Vision

The Northeast Washington Forest Vision (NEWFV) CFLRP is located in Northeastern Washington and is bound on the east by the Columbia River, on the north by the Canadian border, and is composed mostly of Colville National Forest Lands (figure 3.1). The CFLRP boundary contains over 916,000 acres and the 20 km buffer analysis area accounts for over 2,300,000 acres. The Lane Creek RAWS was used to derive weather inputs used in the fire simulations.

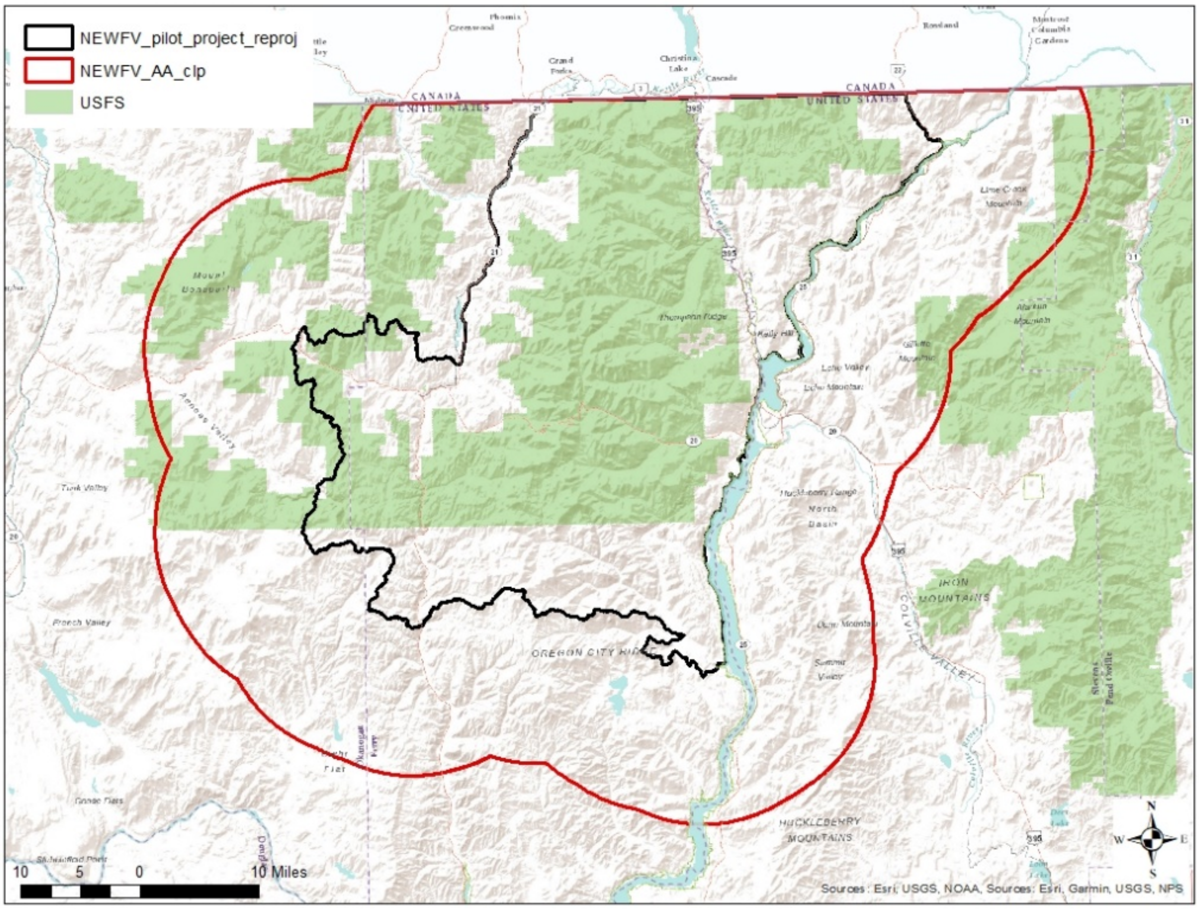


Figure 3.1: Northeast Washington Forest Vision CFLRP boundary and analysis area.

During the analysis period from 2012 to 2019, a total of 185,750 acres within the Northeast Washington Forest Vision project area experienced some type of treatment or disturbance. This included 146,550 acres of fire (16% of project area); 28,915 acres of mechanical add treatments (3%); and 10,290 acres of mechanical remove treatments (1%). For the Fuel Disturbance information used to modify fuels data for the post-treatment FSim modeling, these categories were subdivided by severity (low, medium, high), and years since disturbance (1, 2-5, 6-10). In areas with overlying treatment polygons, standard rules were employed to categorize the treatment: fire takes precedence over mechanical add which takes precedence over mechanical remove, and so on through the disturbance codes. Similarly, more recent activities take precedence over earlier activities. The acreage by disturbance type and severity are shown in figure 3.2.

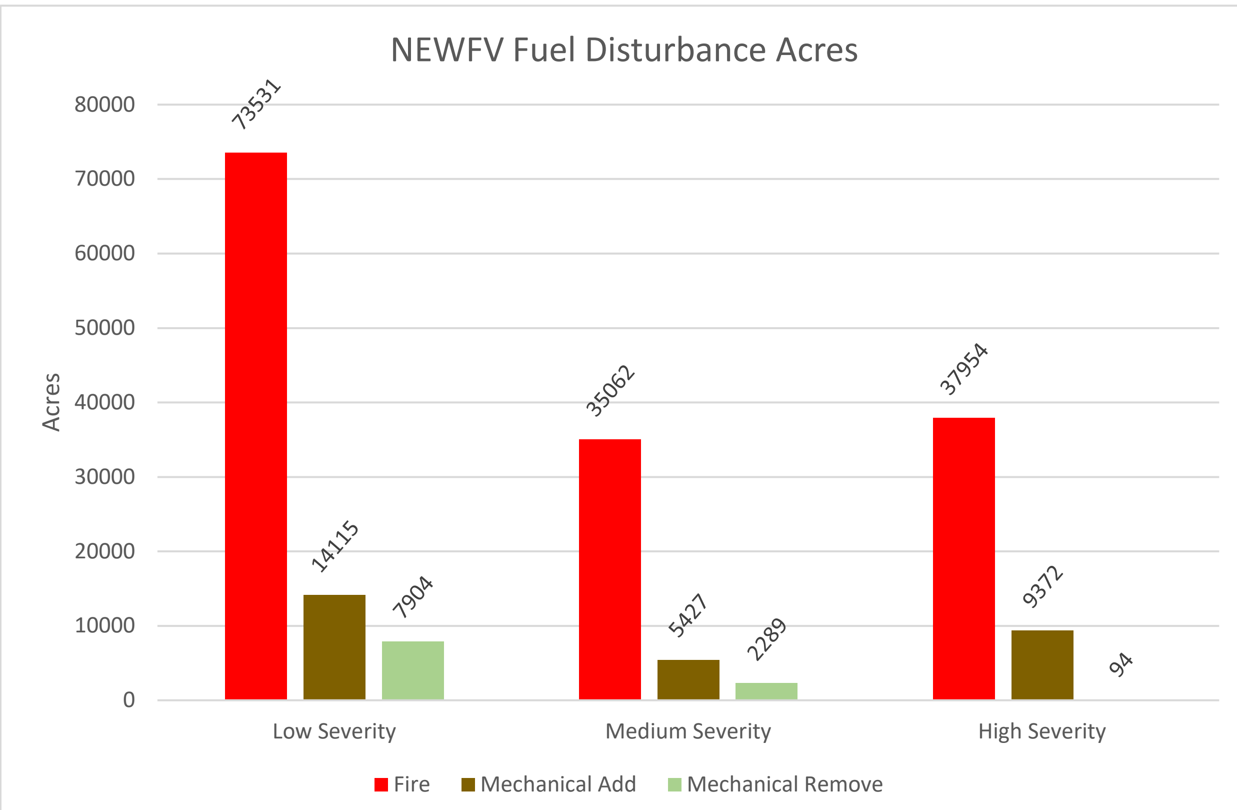


Figure 3.4: Acres of landscape disturbance and treatements by disturbance type and severity for the Northeast Washington Forest Vision CFLRP project area.

The FSim calibration plot for the NEWFV shows the calibration target and results of the initial and post-treatment modeling with respect to the average number of large fires and the average large fire size (figure 3.3). Using the pre-treatment landscape, we did calibration runs of FSim, adjusting input parameters until we fell within the 70% confidence interval of the historic target. Once we met this criterion, we ran final simulation for initial conditions using 10,000 model iterations. After modifying the landscape fuels to account for fire occurrence and treatments, we ran the post-treatment simulation with the same time-step and model parameterization as the initial run.

The calibration plot in figure 3.3 shows the initial simulation was almost right on the calibration target. The results show a decrease in mean annual number of fires per million acres (shown on the X axis) and mean large fire size in the post-treatment simulations.

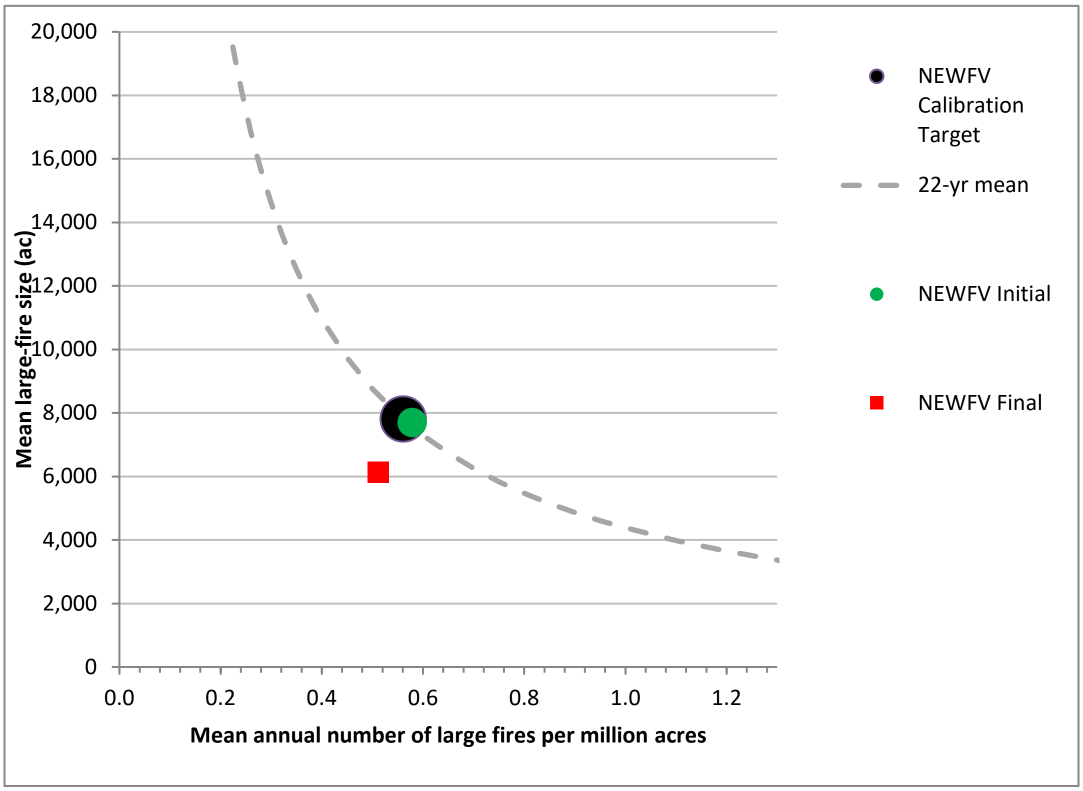


Figure 3.3: Calibration plot for Northeast Washington Forest Vision.

Summary statistics for select FSim outputs and risk metrics are shown in table 3.1. The change in each metric from 2012 to 2019 is shown as a percentage, relative to the initial value. Positive change numbers show an increase after treatment (the number moved further away from zero), while negative numbers show a decrease (moving toward zero). Given the general goal of reducing risk from wildfire while increasing the likelihood of beneficial outcomes, these numbers can be interpreted as follows:

- Decreases in burn probability and expected annual area burned are generally desirable will contribute to reduced risk.
- Decrease in intensity will also contribute to reduced risk.

- If the sum of expected loss (the proposed risk index) move closer to zero, this represents a reduction of risk.
- If the sum of expected benefit increases, this represents a higher likelihood of beneficial outcomes.
- If the sum of expected NVC increases (gets more positive), this represents either a reduction of risk or increase in potential benefit (or both). If the sum of expected NVC decreases (gets more negative), this represents either an increase in risk or decrease in potential benefit (or both).

Table 3.7: Zonal Statistics for Northeast Washington Forest Vision.

	Acres	Average Burn Probability	Expected Annual Area Burned	Sum of Expected Loss (Risk Index)	Sum of Expected Benefit	Sum of Expected NVC
NEWFV 2012	916,261	0.004114	3,769	-627	1,189	563
NEWFV 2019	916,261	0.003046	2,790	-573	860	287
Percent Change		-26.0%	-26.0%	-8.6%	-27.7%	-49.0%

As shown in table 3.1 and subsequent figures, most metrics of wildfire likelihood, burn area, and risk decreased between 2012 and 2019. Average burn probability, and correspondingly expected annual area burned (which is total project area acres x burn probability) both decreased by 26 percent. The proposed risk index (sum of expected loss) also decreased, moving closer to zero and indicating a reduction in wildfire risk. The sum of expected benefit, however, also decreased by nearly 28% (which is to say there was less expected benefit from fire) over the analysis period and that impacted the sum of expected Net Value Change in the post-treatment landscape. The relationship between expected NVC and its component pieces of expected loss and expected benefit can also be viewed graphically in figure 3.4.

Overall, the sum of expected NVC remains positive in the 2019 landscape and indicates an overall positive impact of fire on the Highly Valued Resources and Assets (HVRA) used in the analysis.

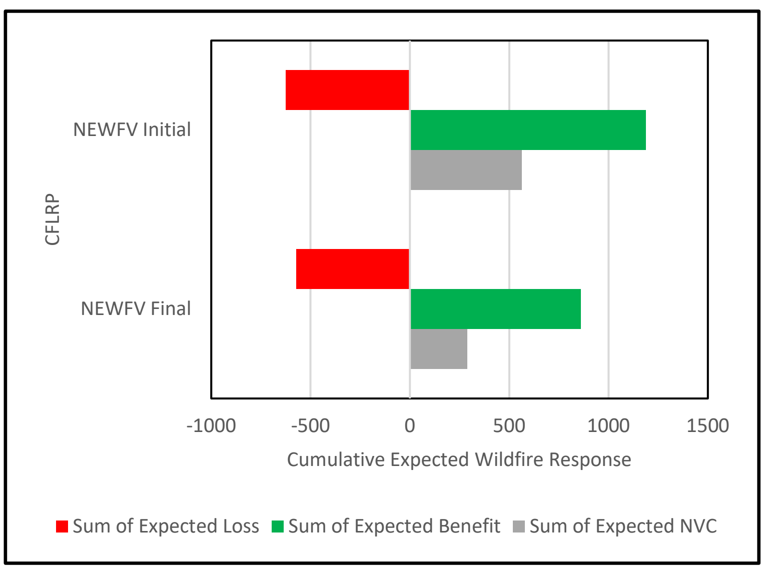


Figure 3.4: Cumulative Expected Wildfire Response for the Northeast Washington Forest Vision CFLRP.

Looking directly at the estimates of wildfire likelihood and intensity from FSim can also help to understand how landscape changes affected expected fire behavior. As shown in table 3.1, burn probability decreased from 2012 to 2019 overall, but changes in probability varied across the project area (figure 3.5). Generally, increases and decreases in burn probability were moderate. Major increases or decreases in burn probability were limited spatially to relatively small patches.

Intensity outputs from FSim are categorized into Fire Intensity Level (FIL) classes, which are described by flame lengths. For each pixel, FSim gives us the conditional probability for each FIL class. In other words, if a fire occurs, what are the chances of seeing each of six flame length classes? Probabilities for each pixel sum to one. These six FIL classes are:

Figure 4: Cumulative Expected Wildfire Response for the Northeast Washington Forest Vision CFLRP

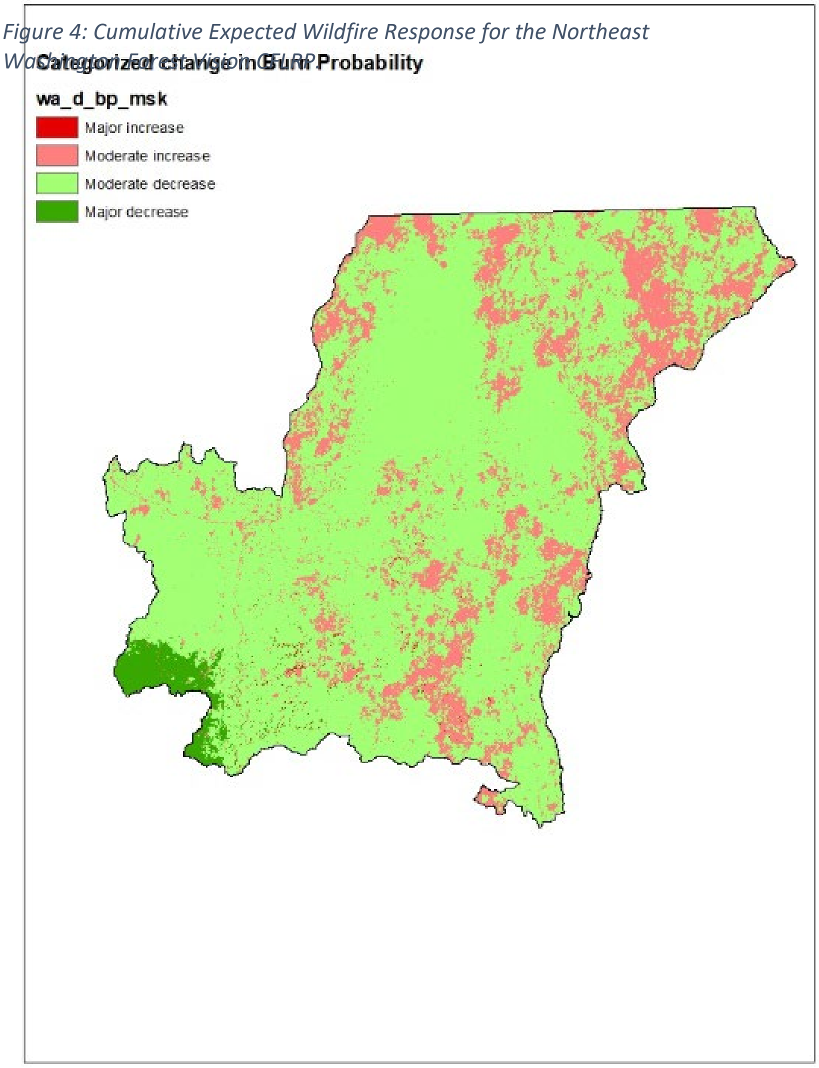


Figure 3.5: Difference in Burn Probability for the Northeast Washington Forest Vision CFLRP. Areas shown in green have decreased likelihood of wildfire in the post-treatment landscape, while areas in red have increased likelihood of wildfire.

Class	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6
Flame length (ft)	0-2	2-4	4-6	6-8	8-12	12+

Flame Length Exceedance Probability (FLEP) is a measure that aggregates the FIL probabilities to make interpretation easier. FLEP is the probability a given pixel will experience a flame length equal to or greater than a certain value. It is calculated by simply summing the probabilities for FIL classes above a flame length of interest. For example, FLEP6 is the probability that a pixel will experience flame length greater than 6 feet and is the sum of probabilities for FIL 4, FIL 5, and FIL 6 (FIL 4 being 6-8 feet). FLEP8 is similar but is the probability of experiencing 8-foot flame lengths or greater and is the sum of probabilities for FIL 5 and FIL 6.

We calculated FLEP6 and FLEP8 for initial and post-treatment conditions (table 3.2, figure 3.6). We spilt our calculations in to two categories. The first is for the entire CFLRP project area, while the second is calculated only for “treated” areas. The treated areas correspond to the final Fuel Disturbance layer (FDIST) used in modifying LANDFIRE fuels for the 2019 assessment. These include all treatments and fires.

Across the entire project area, the data show an overall decrease in FLEP6 and FLEP8, 6.5% and 1.1%, respectively (table 3.2, figure 3.6). When looking only at “treated” areas, we observed a more substantial change in both FLEP classes. In the post-treatment landscape by FLEP6 was reduced by 50.1%, while FLEP8 was reduced by 52.4%, relative to the 2012 landscape.

Table 3.8: Mean flame Length Exceedance Probabilities (FLEP6 and FLEP8) for entire project area and “treated” areas only. Negative Percent Change indicates a decrease in the probability post-treatment.

		Entire Project Area		Treatment Areas Only (FACTS and FIRE)	
		Mean	Percent Change	Mean	Percent Change
FLEP6	Initial	0.4389		0.4414	
	Post	0.4105	-6.5%	0.2201	-50.1%
FLEP8	Initial	0.2799		0.2792	
	Post	0.2767	-1.1%	0.1330	-52.4%

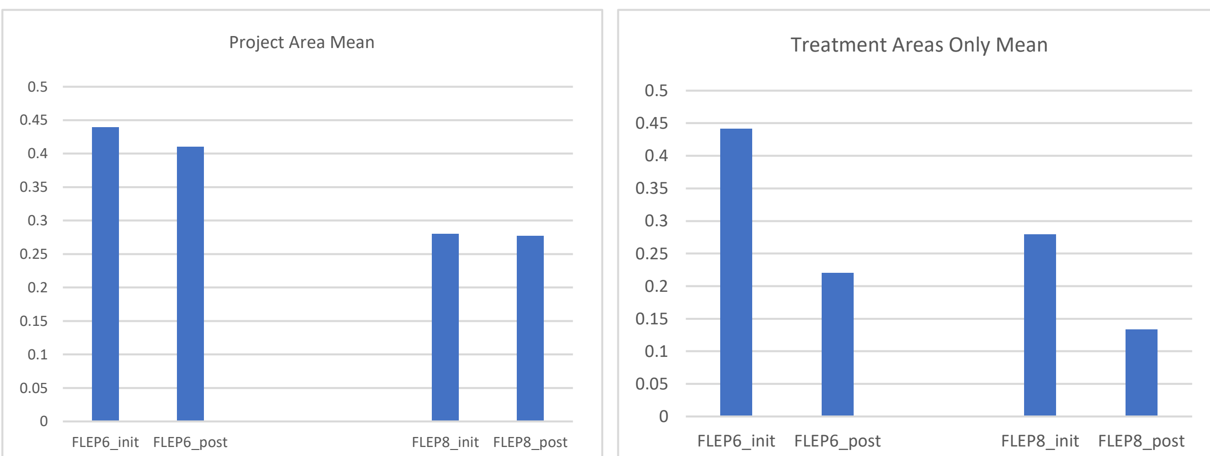


Figure 3.6: FLEP6 and FLEP8 probabilities for CFLRP boundary and treatment specific areas.

As with burn probability, changes in expected wildfire intensity between 2012 and 2019 were spatially variable (figure 3.7). In general, the areas with major increase in FLEP6 and FLEP8 are outside of treated areas. Decreases in FLEP6 and FLEP8 occurred across the project area, but are concentrated within treatment areas.

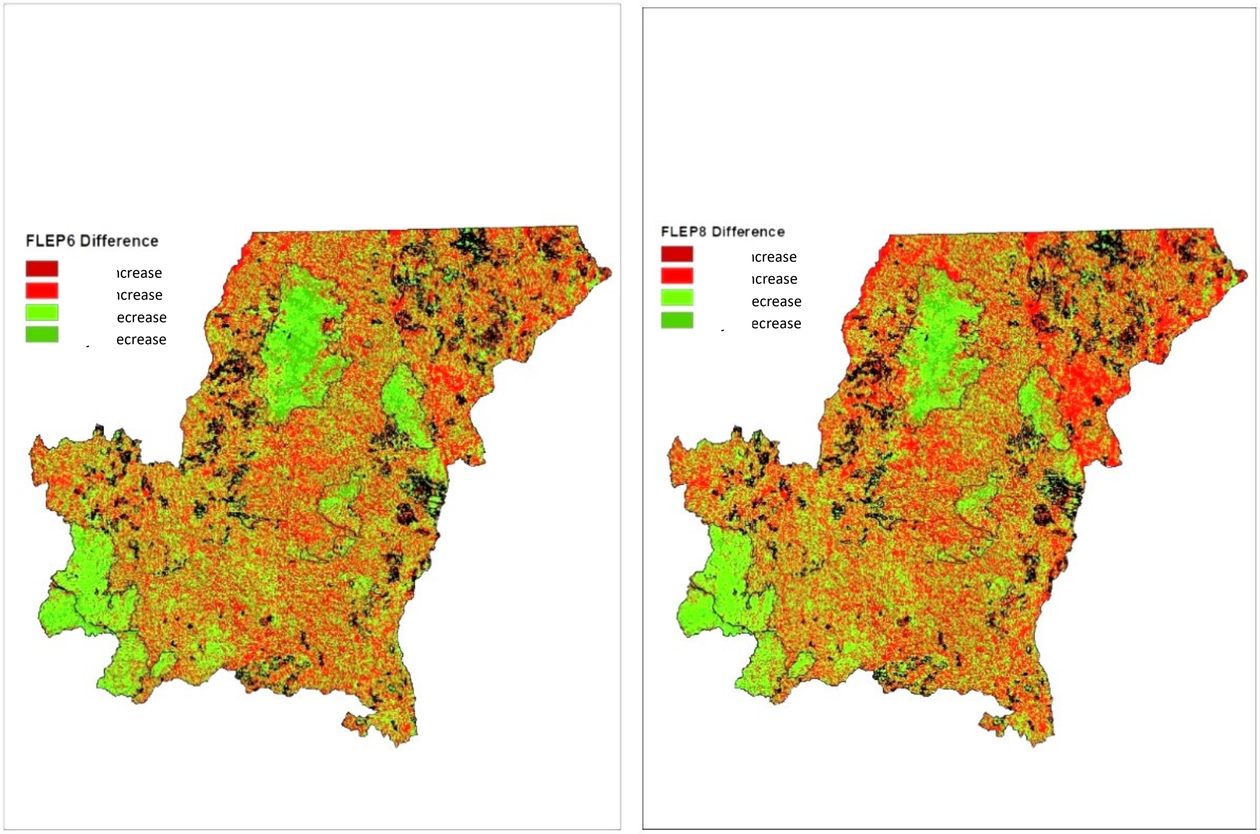


Figure 3.7: Difference of FLEP 6 and FLEP8. Positive numbers indicate and improvement in Final FLEP probabilities. Polygons represent fire and treatment areas.

Discussion – Northeast Washington Forest Vision

Generally, the NEWFV CFLRP is seeing positive results with respect to simulated fire impacts over the analysis period. The mean annual number of large fires per million acres and the mean large fire size both decreased as shown in the calibration chart. Average burn probability and expected annual area burned both dropped by 26% while the proposed risk index (sum of expected loss) also decreased by 8.6%. The probability of large flame-lengths experienced in the CFLRP, as measured by FLEP6 and FLEP8, all decreased with a dramatic drop of more than 50% for the treated areas in both FLEP classes.

Burn probabilities and expected fire sizes both dropped in the final assessment indicating fewer and smaller fires are expected from the simulations. There was also a large decrease in the sum of expected Net Value Change over time. As this is a summation of the expected benefits and expected losses, it is driven primarily by the decrease in the expected benefits. However, expected NVC remains positive, indicating fire will have an overall positive impact on the HVRAs used in the analysis. Overall, the results of this analysis are sensitive to the HVRAs included and the way that effects were quantified with response functions. We used consistent HVRAs and parameters in this pilot project for the purpose of testing and consistency, but future work could explore local adjustments to fine-tune results for the NEWFV project area.

Missouri Pine and Oak Woodlands

The Missouri Pine and Oak Woodlands (MOPOW) CFLRP is in Southcentral Missouri and is composed of Mark Twain National Forest lands, various State of Missouri public lands, properties owned by The Nature Conservancy, and various other public and private landowners. The CFLRP encompasses approximately 443,000 acres while the 20 km buffer increases the analysis area to more than 2.3 million acres (figure 4.1). Data from the Ava RAWS station was used to derive weather fields required for the fire simulations.

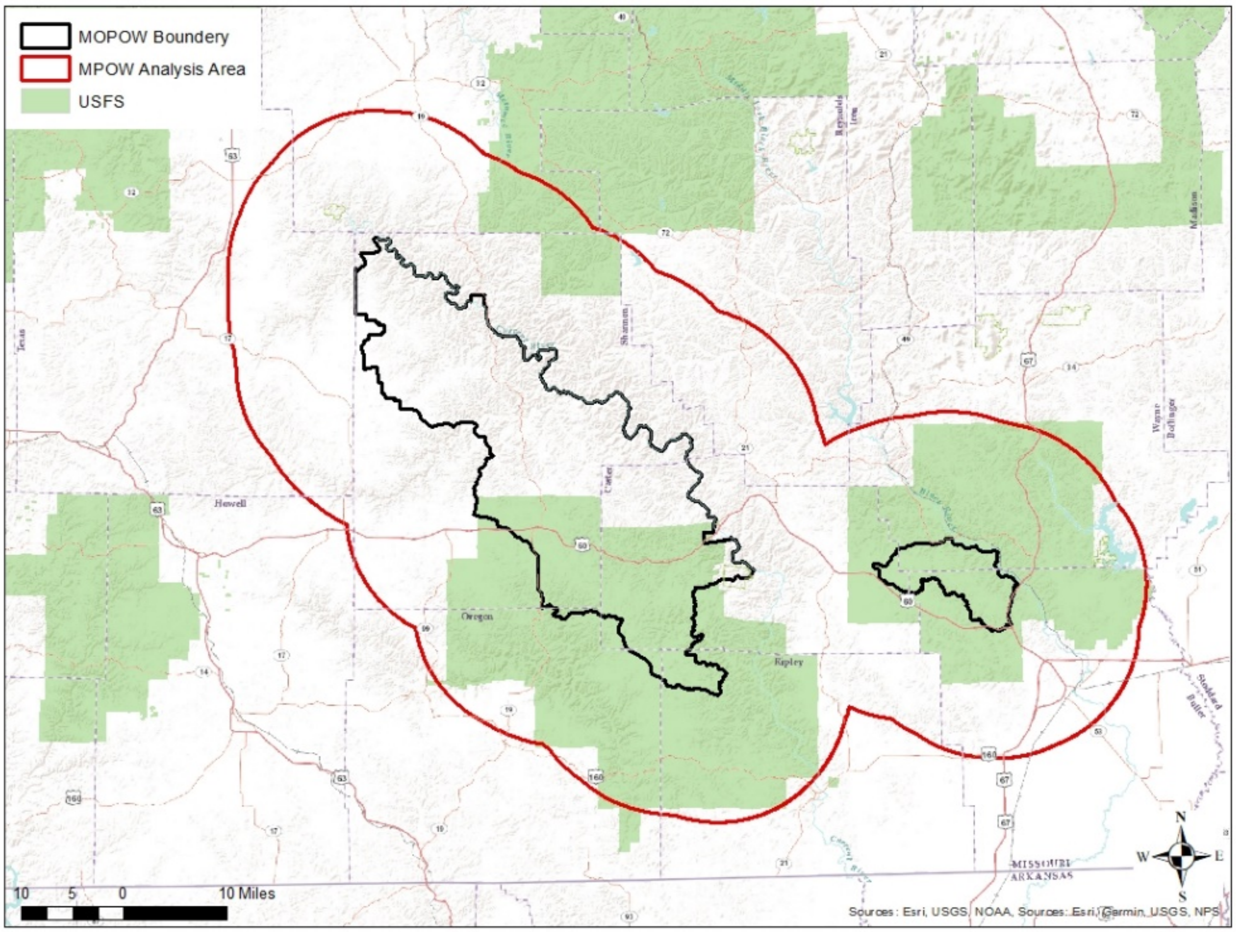


Figure 4.1: Missouri Pine and Oak Woodlands CFLRP boundary and analysis area.

During the analysis period from 2012 to 2019, approximately 122,465 acres within the Missouri Pine and Oak Woodlands project area experienced some type of treatment or disturbance. This included 104,200 acres of fire (24% of project area); 2,700 acres of mechanical add treatments (<1%); and 15,570 acres of mechanical remove treatments (4%). For the Fuel Disturbance information used to modify fuels data for the post-treatment FSim modeling, these categories were subdivided by severity (low, medium, high), and years since disturbance (1, 2-5, 6-10). In areas with overlying treatment polygons, standard rules were employed to categorize the treatment: fire takes precedence over mechanical add which takes precedence over mechanical remove, and so on through the disturbance codes. Similarly, more recent activities take precedence over earlier activities. The acreage by disturbance type and severity are shown in figure 4.2.

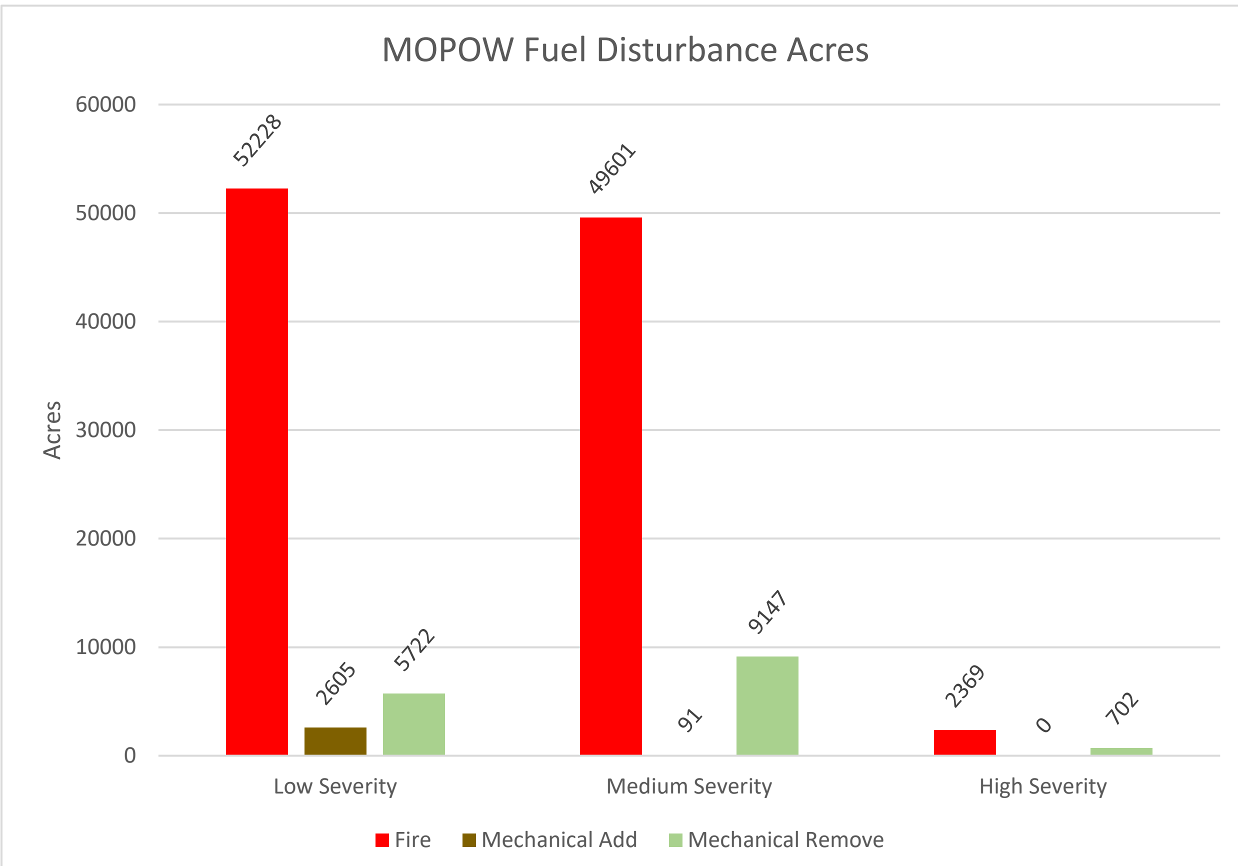


Figure 4.5: Acres of landscape disturbance and treatements by disturbance type and severity for the Missouri Pine and Oak Woodlands CFLRP project area.

The FSim calibration plot for the MOPOW shows the calibration target and results of the initial and post-treatment modeling with respect to the average number of large fires and the average large fire size (figure 4.3). Using the pre-treatment landscape, we did calibration runs of FSim, adjusting input parameters until we fell within the 70% confidence interval of the historic target. Once we met this criterion, we ran final simulation for initial conditions using 10,000 model iterations. After modifying the landscape fuels to account for fire occurrence and treatments, we ran the post-treatment simulation with the same time-step and model parameterization as the initial run. The final simulation showed a slight drop in both Mean large-fire size and Mean annual number of large fires per million acres.

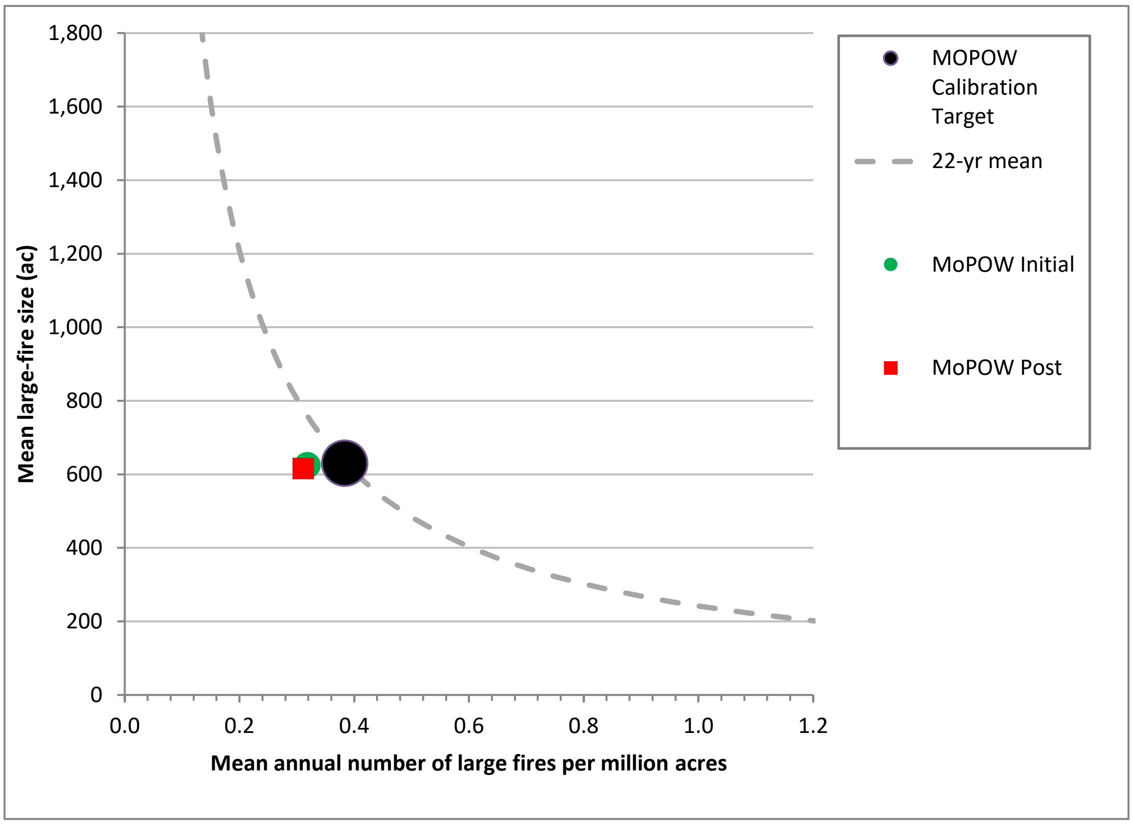


Figure 4.3: Calibration plot for Missouri Pine and Oak Woodlands CFLRP .

Summary statistics for select FSim outputs and risk metrics are shown in table 4.1. The change in each metric from 2012 to 2019 is shown as a percentage, relative to the initial value. Positive change numbers show an increase after treatment (the number moved further away from zero), while negative numbers show a decrease (moving toward zero). Given the general goal of reducing risk from wildfire while increasing the likelihood of beneficial outcomes, these numbers can be interpreted as follows:

- Decreases in burn probability and expected annual area burned are generally desirable will contribute to reduced risk.
- Decrease in intensity will also contribute to reduced risk.
- If the sum of expected loss (the proposed risk index) move closer to zero, this represents a reduction of risk.

- If the sum of expected benefit increases, this represents a higher likelihood of beneficial outcomes.
- If the sum of expected NVC increases (gets more positive), this represents either a reduction of risk or increase in potential benefit (or both). If the sum of expected NVC decreases (gets more negative), this represents either an increase in risk or decrease in potential benefit (or both).

Table 4.9: Zonal Statistics for Missouri Pine and Oak Woodlands.

	Acres	Average Burn Probability	Expected Annual Area Burned	Sum of Expected Loss (Risk Index)	Sum of Expected Benefit	Sum of Expected NVC
MOPOW 2012	443,797	0.00023	101	-30	45	15
MOPOW 2019	443,797	0.000216	95	-33	41	8
Percent Change		-6.1%	-5.9%	10.4%	-8.0%	-44.6%

As might be expected, the results for the MOPOW project are nuanced and require some interpretation. Average burn probability and expected annual area burned decreased slightly in the 2019 landscape by 6.1 and 5 percent, respectively. Conversely, the overall risk increased, the expected benefits decreased, and the Sum of Expected NVC dropped.

The changes in expected NVC and its component pieces of expected loss and expected benefit can also be viewed graphically (figure 4.4). The sum of expected loss increased slightly (moved away from zero), and the sum of expected benefit decreased slightly (moved toward zero). Both moved in the opposite direction as would be expected for risk reduction. The overall expected NVC compounded the changes in loss and benefit, showing a 44.6 percent decrease. It is important to note, however, that the expected loss, benefit, and NVC numbers here are very small numbers. Because of this, a small change has a large impact on the calculated percent change. Overall, the sum of expected NVC is positive in the pre-treatment and post-treatment landscapes, indicating an overall positive impact of fire on the Highly Valued Resources and Assets (HVRA) used in the analysis.

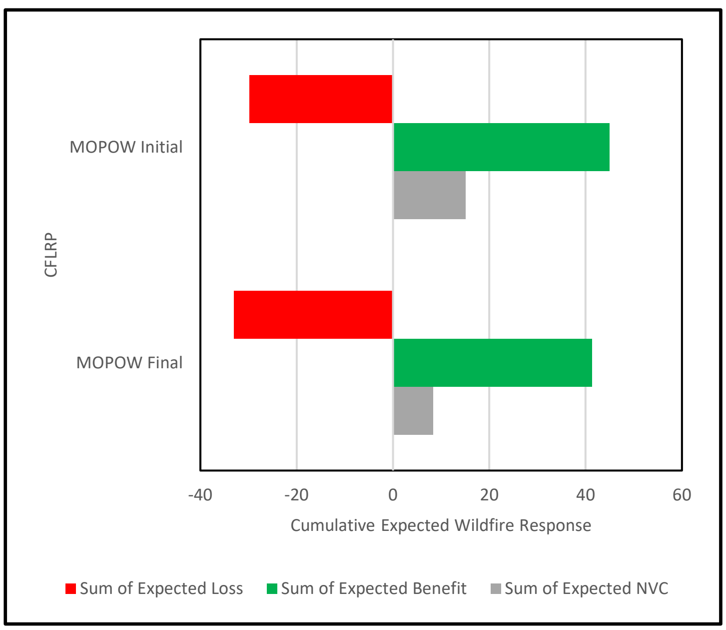


Figure 4.4: Cumulative Expected Wildfire Response for the Missouri Pine and Oak Woodlands CFLRP.

Looking directly at the estimates of wildfire likelihood and intensity from FSim can also help to understand how landscape changes affected expected fire behavior. As shown in table 4.1, burn probability decreased slightly from 2012 to 2019 overall, but changes in probability varied across the project area (figure 4.5). Generally, increases and decreases in burn probability were moderate. Major increases or decreases in burn probability were limited spatially to relatively small patches.

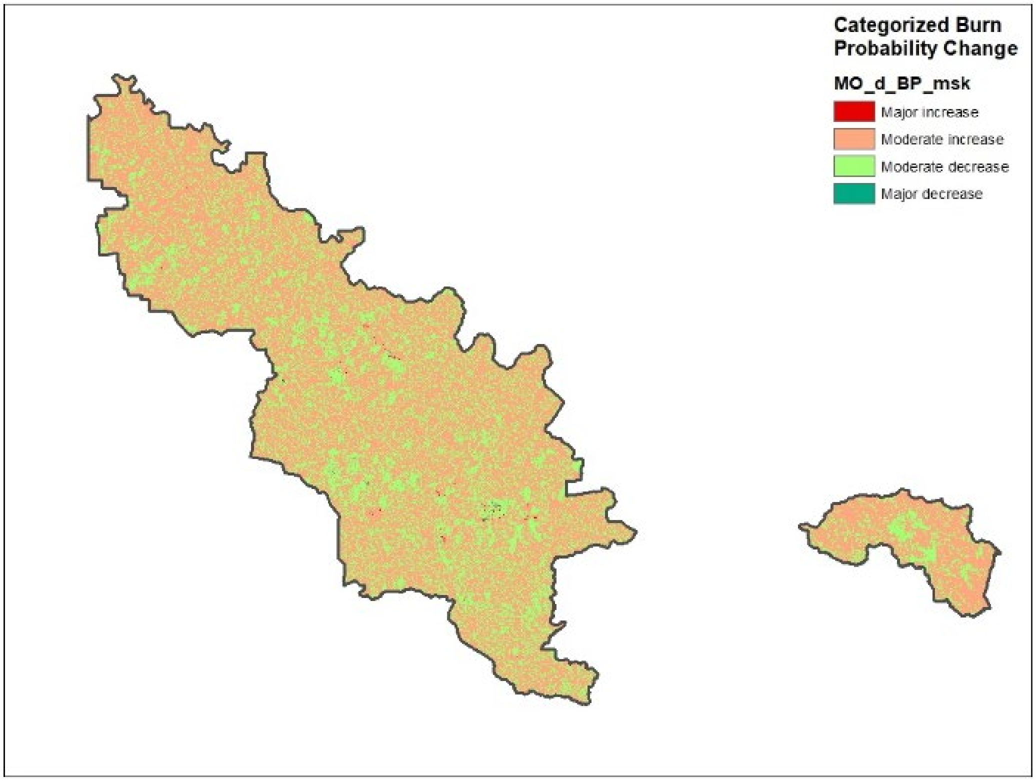


Figure 4.5: Difference in Burn Probability for the Missouri Pine and Oak Woodlands CFLRP. Areas shown in green have decreased likelihood of wildfire in the post-treatment landscape, while areas in red have increased likelihood of wildfire.

Intensity outputs from FSim are categorized into Fire Intensity Level (FIL) classes, which are described by flame lengths. For each pixel, FSim gives us the conditional probability for each FIL class. In other words, if a fire occurs, what are the chances of seeing each of six flame length classes? Probabilities for each pixel sum to one. These six FIL classes are:

Class	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6
Flame length (ft)	0-2	2-4	4-6	6-8	8-12	12+

Flame Length Exceedance Probability (FLEP) is a measure that aggregates the FIL probabilities to make interpretation easier. FLEP is the probability a given pixel will experience a flame length equal to or greater than a certain value. It is calculated by simply summing the probabilities for FIL classes above a flame length of interest. For example, FLEP6 is the probability that a pixel will experience flame length greater than 6 feet and is the sum of probabilities for FIL 4, FIL 5, and FIL 6 (FIL 4 being 6-8 feet). FLEP8 is similar but is the probability of experiencing 8-foot flame lengths or greater and is the sum of probabilities for FIL 5 and FIL 6.

We calculated FLEP6 and FLEP8 for initial and post-treatment conditions (table 4.2, figure 4.6). We spilt our calculations in to two categories. The first is for the entire CFLRP project area, while the second is calculated only for "treated" areas. The treated areas correspond to the final Fuel Disturbance layer (FDIST) used in modifying LANDFIRE fuels for the 2019 assessment. These include all treatments and fires.

Both FLEP6 and FLEP8 showed increases for the treated areas and the entire project area (table 4.2, figure 4.6). While the calculated percent changes shown in the table suggest a dramatic increase in the likelihood of experiencing large flame lengths in the final analysis, the magnitude of the probabilities need to be considered. Both FLEP6 and FLEP8 probabilities are an order of magnitude lower than probabilities seen in other CFLRPs. Thus, the calculated percent change is the result of a "small number" effect where small differences in small numbers result in a large percent change. The FIL probabilities sum to 1. Using the FLEP6 final as an example, the average likelihood of flame lengths being *less than* six feet is nearly 96% (e.g. 1 – 0.04329 = 0.95671)

Table 4.10: Mean flame Length Exceedance Probabilities (FLEP6 and FLEP8) for entire project area and "treated" areas only. Negative Percent Change indicates a decrease in the probability post-

		Entire Project Area		Treatment Areas Only (FACTS and FIRE)	
		Mean	Percent Change	Mean	Percent Change
FLEP6	Initial	0.0389		0.0500	
	Final	0.0433	11.4%	0.0619	23.6%
FLEP8	Initial	0.0129		0.0214	
	Final	0.0158	22.6%	0.0290	35.3%

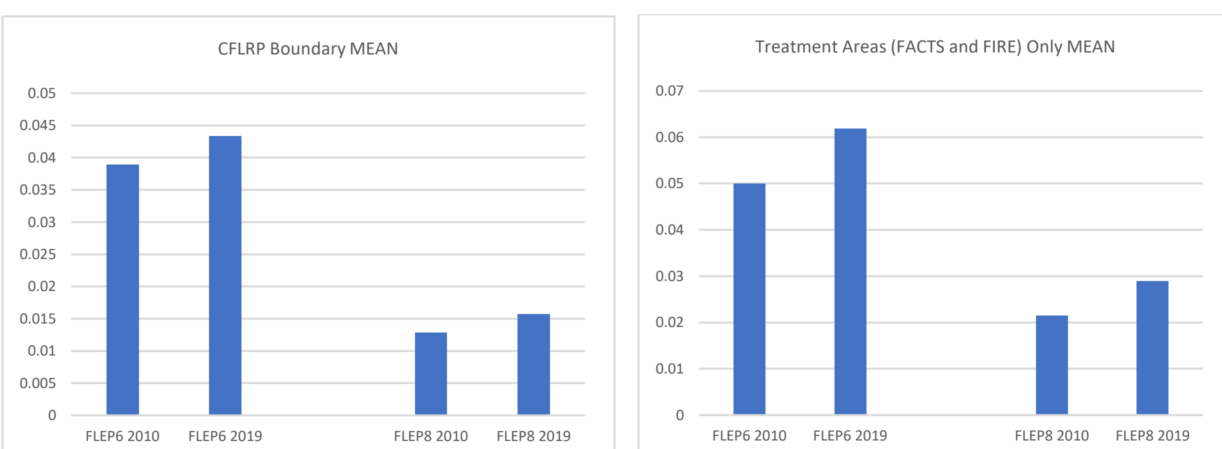


Figure 4.6: FLEP6 and FLEP8 probabilities for CFLRP boundary and treatment specific areas.

As with burn probability, changes in expected wildfire intensity between 2012 and 2019 were spatially variable (figure 4.7). Generally, the differences in FLEP6 and FLEP8 showed that the increases in were moderate.

Discussion – Missouri Pine and Oak Woodlands

As discussed above, the results of this analysis are complex and nuanced. There was a decrease in burn probability and expected annual area burned for the Missouri Pine and Oak Woodlands Restoration Project. Similarly, there was a decrease in expected benefit, a decrease in expected NVC, and an increase in the proposed risk index (expected loss). FLEP6 and FLEP8 probabilities also increased in the final assessment. When interpreting these results, one must consider that all numbers for the MOPOW project area – including burn probability, expected benefit and loss, NVC, and all FLEP categories – are an order of magnitude less than those for other CFLRP areas. It is possible that as applied, our FSim and risk assessment methodologies are unable to capture important information needed to understand the effects of treatments and fire in this type of mixed pine-oak ecosystem.

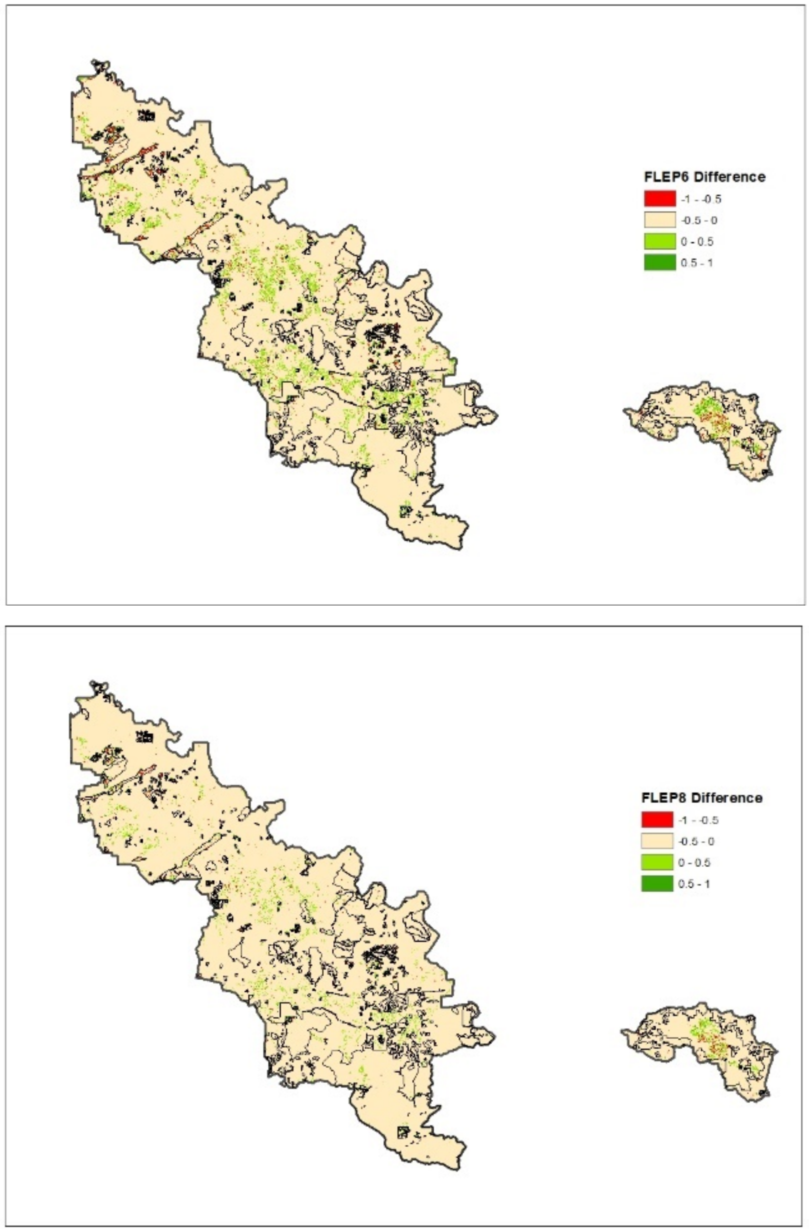


Figure 4.7: Difference of FLEP 6 and FLEP8. Positive numbers indicate and improvement in Final FLEP probabilities. Polygons represent fire and treatment areas.

Another consideration is the standardized criterion used here to define a “large” fire. The fire regime in the Ozarks of Missouri may require a different threshold for defining a large fire for FSim modeling to provide more useful results. The results of this analysis are also sensitive to the HVRAs included and the way that effects were quantified with response functions. We used consistent HVRAs and parameters in this pilot project for the purpose of testing and consistency, but future work could explore local adjustments to fine-tune results for the MOPOW project area.

Accelerating Long-leaf Pine Restoration

The Accelerating Longleaf Pine Restoration (ALLPR) CFLRP straddles the Florida-Georgia border and is primarily composed of Federal lands (Osceola National Forest and Okefenokee National Wildlife Refuge) but includes private industrial, private non-industrial, and State ownerships (figure 5.1). The CFLRP boundary encompasses approximately 567,000 acres while the 20 km buffered analysis area is approximately 1.8 million acres. The Olustee RAWS station provided the weather streams required for the simulations.

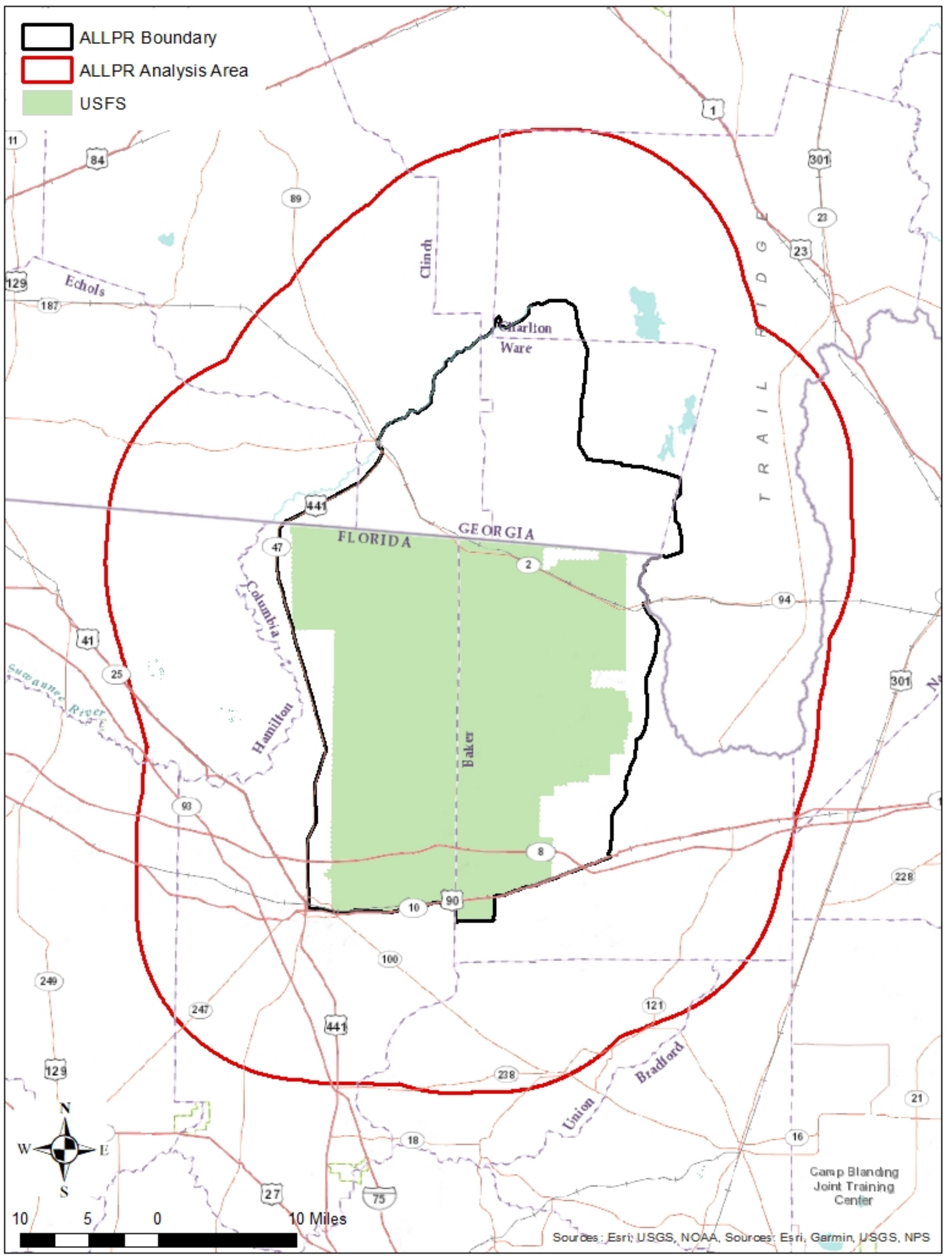


Figure 5.1: Accelerating Longleaf Pine Restoration CFLRP boundary and analysis area.

During the analysis period from 2012 to 2019, approximately 447,820 acres within the Accelerating Longleaf Pine Restoration project area experienced some type of treatment or disturbance. This included 384,680 acres of fire (68% of project area); 43,380 acres of mechanical add treatments (8%); and 19,760 acres of mechanical remove treatments (4%). For the Fuel Disturbance information used to modify fuels data for the post-treatment FSim modeling, these categories were subdivided by severity (low, medium, high), and years since disturbance (1, 2-5, 6-10). In areas with overlying treatment polygons, standard rules were employed to categorize the treatment: fire takes precedence over mechanical add which takes precedence over mechanical remove, and so on through the disturbance codes. Similarly, more recent activities take precedence over earlier activities. The acreage by disturbance type and severity are shown in figure 5.2.

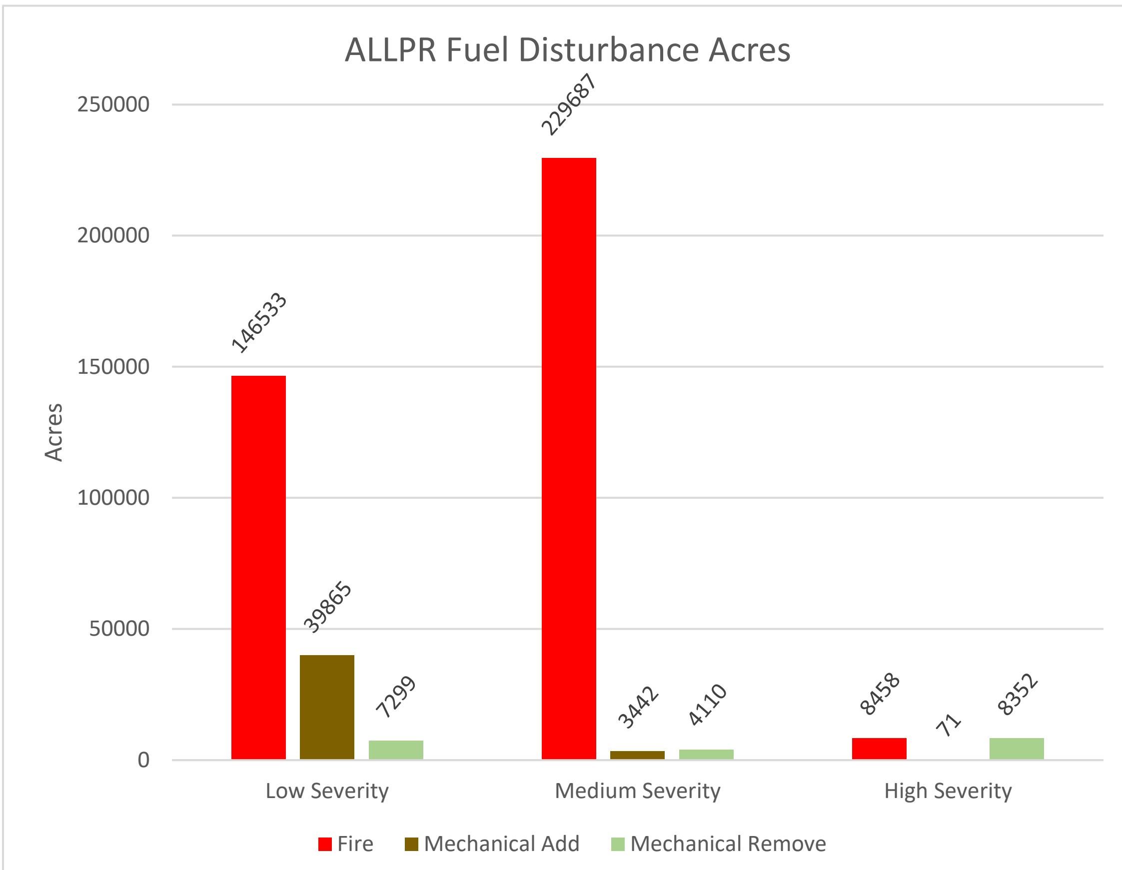


Figure 5.6: Acres of landscape disturbance and treatements by disturbance type and severity for the Accelerating Longleaf Pine Restoration CFLR project area.

The FSim calibration plot for the ALLPR shows the calibration target and results of the initial and post-treatment modeling with respect to the average number of large fires and the average large fire size (figure 5.3). Using the pre-treatment landscape, we did calibration runs of FSim, adjusting input parameters until we fell within the 70% confidence interval of the historic target. Once we met this criterion, we ran final simulation for initial conditions using 10,000 model iterations. After modifying the landscape fuels to account for fire occurrence and treatments, we ran the post-treatment simulation with the same time-step and model parameterization as the initial run. The post-treatment simulation results showed a decrease in both the mean annual number of large fires per million acres (shown on the X axis) and the mean large fire size when compared to the 2012 simulation.

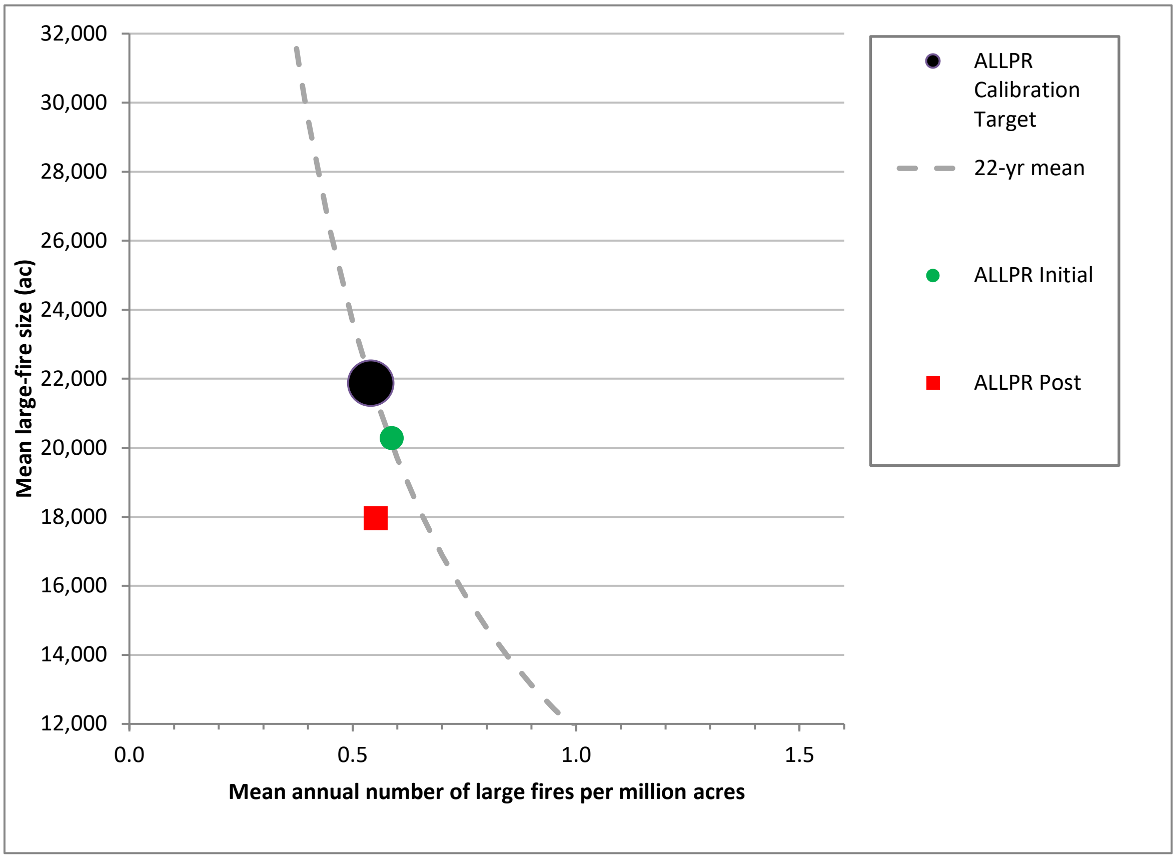


Figure 5.3: Calibration plot for Accelerating Longleaf Pine Restoration project.

Summary statistics for select FSim outputs and risk metrics are shown in table 5.1. The change in each metric from 2012 to 2019 is shown as a percentage, relative to the initial value. Positive change numbers show an increase after treatment (the number moved further away from zero), while negative numbers show a decrease (moving toward zero). Given the general goal of reducing risk from wildfire while increasing the likelihood of beneficial outcomes, these numbers can be interpreted as follows:

- Decreases in burn probability and expected annual area burned are generally desirable will contribute to reduced risk.
- Decrease in intensity will also contribute to reduced risk.

- If the sum of expected loss (the proposed risk index) move closer to zero, this represents a reduction of risk.
- If the sum of expected benefit increases, this represents a higher likelihood of beneficial outcomes.
- If the sum of expected NVC increases (gets more positive), this represents either a reduction of risk or increase in potential benefit (or both). If the sum of expected NVC decreases (gets more negative), this represents either an increase in risk or decrease in potential benefit (or both).

Table 5.1: Zonal statistics for the Accelerating Longleaf Pine

	Acres	Average Burn Probability	Expected Annual Area Burned	Sum of Expected Loss (Risk Index)	Sum of Expected Benefit	Sum of Expected NVC
ALLPR 2012	566,960	0.020583	11,669	-3,587	1,603	-1,984
ALLPR 2019	566,960	0.014104	7,996	-2,581	1,263	-1,318
Percent Change		-31.5%	-31.5%	-28.0%	-21.2%	-33.6%

The results for the ALLPR (table 5.1) show the average burn probability and expected annual area burned both decreased by 31.5 percent. The proposed risk index (sum of expected loss) showed improvement, decreasing by 28 percent. Expected benefits also decreased in the final analysis. Sum of Expected NVC, which is the sum of expected loss and benefit became less negative due to the larger drop in Expected Loss.

The changes in expected NVC and its component pieces of expected loss and expected benefit can also be viewed graphically (figure 5.4). The sum of expected benefit decreased by roughly 21 percent. However, the sum of expected NVC improved by nearly 34 percent, driven by the 28 percent improvement in sum of expected loss. While the expected NVC remained negative in both assessments, the post assessment is less negative, showing a reduction of wildfire risk with respect to the HVRAs used in the analysis.

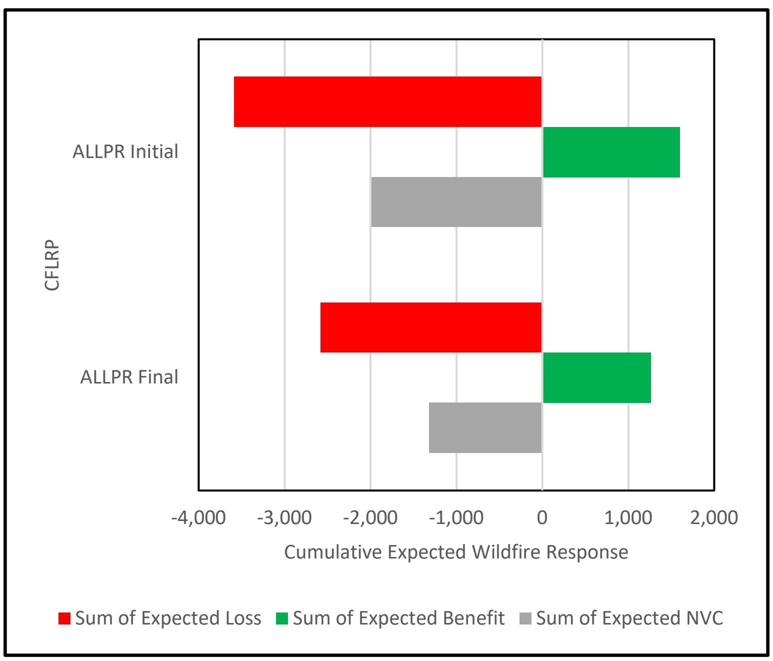


Figure 5.4: Cumulative Expected Wildfire Response for the Accelerating Longleaf Pine Restoration CFLRP.

Looking directly at the estimates of wildfire likelihood and intensity from FSim can also help to understand how landscape changes affected expected fire behavior. As shown in table 5.1, burn probability decreased from 2012 to 2019 overall, but changes in probability varied across the project area (figure 5.5). Generally, increases and decreases in burn probability were moderate. Major increases or decreases in burn probability were limited spatially to relatively small patches.

Intensity outputs from FSim are categorized into Fire Intensity Level (FIL) classes, which are described by flame lengths. For each pixel, FSim gives us the conditional probability for each FIL class. In other words, if a fire occurs, what are the chances of seeing each of six flame length classes? Probabilities for each pixel sum to one. These six FIL classes are:

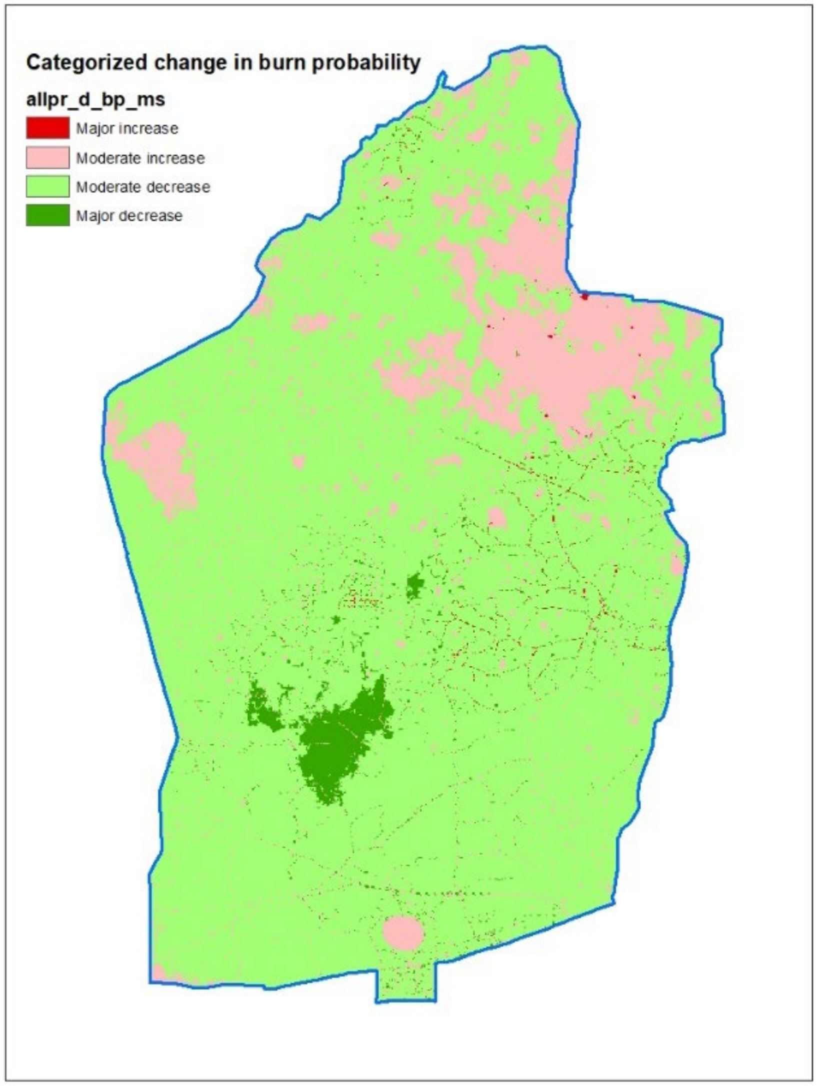


Figure 5.5: Difference in Burn Probability for the Accelerating Longleaf Pine Restoration CFLRP. Areas shown in green have decreased likelihood of wildfire in the post-treatment landscape, while areas in red have increased likelihood of wildfire.

Class	FIL 1	FIL 2	FIL 3	FIL 4	FIL 5	FIL 6
Flame length (ft)	0-2	2-4	4-6	6-8	8-12	12+

Flame Length Exceedance Probability (FLEP) is a measure that aggregates the FIL probabilities to make interpretation easier. FLEP is the probability a given pixel will experience a flame length equal to or greater than a certain value. It is calculated by simply summing the probabilities for FIL classes above a flame length of interest. For example, FLEP6 is the probability that a pixel will experience flame length greater than 6 feet and is the sum of probabilities for FIL 4, FIL 5, and FIL 6 (FIL 4 being 6-8 feet). FLEP8 is similar but is the probability of experiencing 8-foot flame lengths or greater and is the sum of probabilities for FIL 5 and FIL 6.

We calculated FLEP6 and FLEP8 for initial and post-treatment conditions (table 5.2, figure 5.6). We spilt our calculations in to two categories. The first is for the entire CFLRP project area, while the second is calculated only for “treated” areas. The treated areas correspond to the final Fuel Disturbance layer (FDIST) used in modifying LANDFIRE fuels for the 2019 assessment. These include all treatments and fires.

Across the entire project area, the data show an overall decrease in the FLEP6 and FLEP8, 10.8 and 12.1 percent, respectively (table 5.2, figure 5.6). When looking at “treated” areas, we observed a moderate improvement in both FLEP classes. In the post-treatment landscape FLEP6 decreased by 12.1%, while FLEP8 was reduced by 13.8%, relative to the 2012 landscape.

Table 5.11: Mean flame Length Exceedance Probabilities (FLEP6 and FLEP8) for entire project area and “treated” areas only. Negative Percent Change indicates a decrease in the probability post-treatment.

		Entire Project Area		Treatment Areas Only (FACTS and FIRE)	
		Mean	Percent Change	Mean	Percent Change
FLEP6	Initial	0.3216		0.3392	
	Post	0.2869	-10.8%	0.2982	-12.1%
FLEP8	Initial	0.1904		0.1984	
	Post	0.1672	-12.1%	0.1710	-13.8%

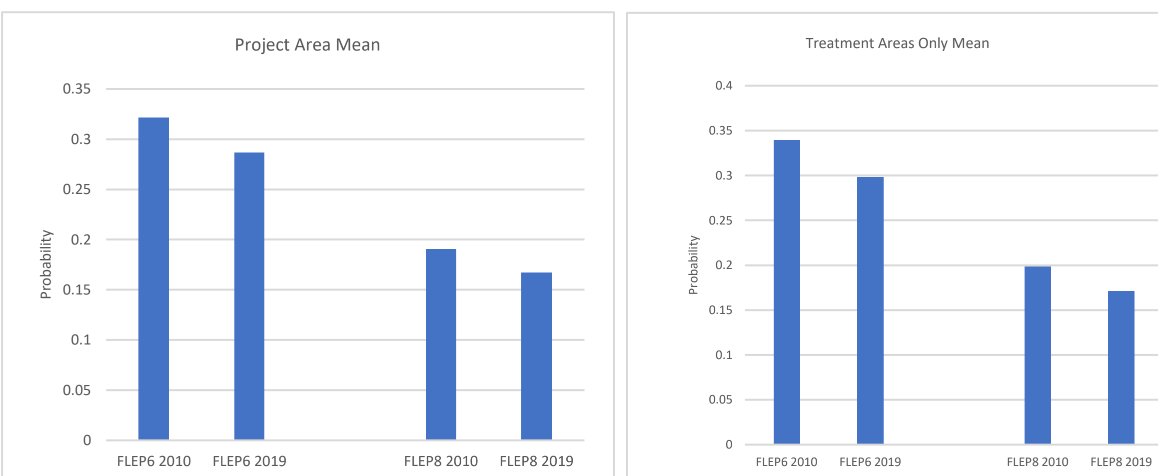


Figure 5.6: FLEP6 and FLEP8 probabilities for CFLRP boundary and treatment specific areas.

As with burn probability, changes in expected wildfire intensity between 2012 and 2019 were spatially variable (figure 5.7). In general, the areas with major increase in FLEP6 and FLEP8 are outside of treated areas. Decreases in FLEP6 and FLEP8 occurred across the project area, but concentrations of major decrease are found within treatment areas.

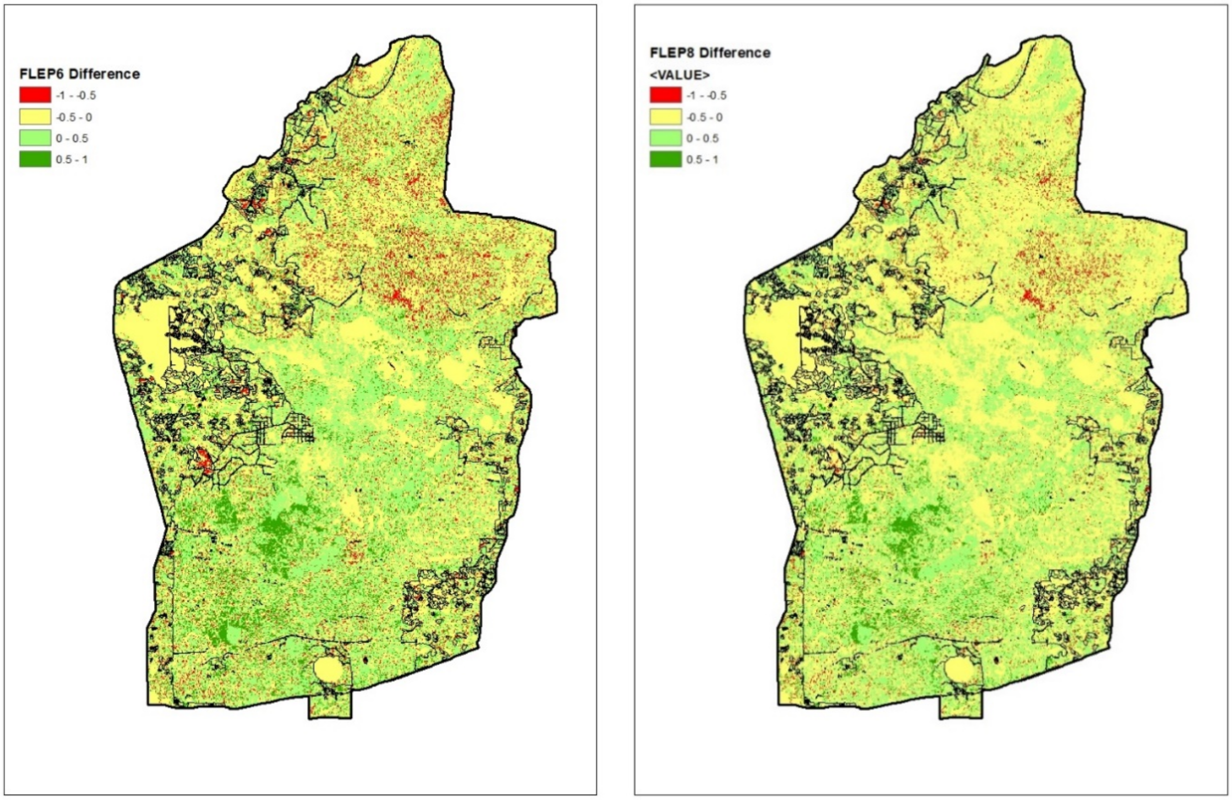


Figure 5.7: Difference of FLEP 6 and FLEP8. Positive numbers indicate and improvement in Final FLEP probabilities. Polygons represent fire and treatment areas.

Discussion – Accelerating Longleaf Pine Restoration

The results for the Longleaf Pine Restoration CFLRP generally provide evidence of risk reduction from 2012 to 2019. The proposed risk index (sum of expected loss), expected NVC, burn probability, and expected annual area burned all decreased, indicating improvement in fire impacts. The sum of expected benefit, however, also decreased, suggesting that the magnitude of benefits from fires occurring in the current landscape would be slightly reduced compared to pre-treatment conditions. The sum of expected NVC is negative in both simulations, but became less negative post-treatment, again pointing to an overall reduction in wildfire risk. Changes in FLEP6 and FLEP8 also show that changes from 2012 to 2019 slightly reduced the probability of high flame lengths.

Overall, the results of this analysis are sensitive to the HVRAs included and the way that effects were quantified with response functions. We used consistent HVRAs, response function, and parameters in this pilot project for the purpose of testing and consistency, but future work could explore local adjustments to fine-tune results for the ALLPR project area.

Comparisons Among Project Areas

Coming soon…

References

Calkin, D.E.; Ager, A.A.; Gilbertson-Day, J.W., eds. 2010. Wildfire risk and hazard: procedures for the first approximation. General Technical Report RMRS-GTR-235 Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 62 p.

Dillon, Gregory K. In Press. Results and application of the National Wildfire Risk Assessment. In: Hood, Sharon M.; Drury, Stacy; Steelman, Toddi; and Steffens, Ron, eds. Proceedings of the Fire Continuum – preparing for the future of wildland fire; 2018 May 21-24; Missoula, MT. Proceedings RMRS-P. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Online.

Finney, Mark A. 2005. The challenge of quantitative risk analysis for wildland fire. Forest Ecology and Management. 211: 97-108.

Finney, Mark A.; McHugh, Charles W.; Grenfell, Isaac C.; Riley, Karen L.; Short, Karen C. 2011. A simulation of probabilistic wildfire risk components for the continental United States. Stochastic Environmental Research and Risk Assessment. 25(7):973-1000. https://doi.org/10.1007/s00477-011-0462-z

Scott, J.H., Thompson, M.P., Calkin, D.E., 2013. A wildfire risk assessment framework for land and resource management. Gen. Tech. Rep. RMRS-GTR-315. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 92 p.

Thompson, Matthew P.; Calkin, David E.; Finney, Mark A.; Ager, Alan A.; Gilbertson-Day, Julie W. 2011. Integrated national-scale assessment of wildfire risk to human and ecological values. Stochastic Environmental Research and Risk Assessment 25:761-780. https://doi.org/10.1007/s00477-011-0461-0

Thompson, M.P.; Zimmerman, T.; Mindar, D.; [et al.]. 2016. Risk terminology primer: Basic principles and a glossary for the wildland fire management community. Gen. Tech. Rep. RMRS-GTR-349. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 13 p.

USDA Office of Inspector General [OIG]. 2016. Forest Service wildland fire activities – Hazardous fuels reduction. Audit Rep. 08601-0004-41. Washington, DC: U.S. Department of Agriculture. https://www.usda.gov/oig/webdocs/08601-0004-41.pdf [Accessed 2019 November 15].