USDA, Forest Service
Collaborative Forest Landscape Restoration Program

# Wildland Fire Management Risk and Cost Analysis Tools Package **(R-CAT):**

# User's Guide[1]


January 19, 2010

[1] For assistance with R-CAT and this User's Guide, please contact Keith Stockmann, Economist, USDA Forest Service, kstockmann@fs.fed.us, or Krista Gebert, Regional Economist, USDA Forest Service, kgebert@fs.fed.us

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# Introduction

The Omnibus Public Land Management Act of 2009 includes Title IV: Forest Landscape Restoration. The purpose of this title, and the USDA Forest Service Collaborative Forest Landscape Restoration Program is to conduct hazardous fuel treatments and ecosystem restoration that encourages economic and social sustainability, leverages local resources with national and private resources, reduces wildfire management costs, and addresses the utilization of forest restoration byproducts to offset treatment costs and benefit local economies (http://www.fs.fed.us/restoration/CFLR/index.shtml).

The CFLRP funnels funding from the Forest Service budget to projects, competitively selected through requests for proposals, to cover up to 50 percent of fuel reduction and ecological restoration treatment implementation and monitoring costs on National Forest System (NFS) lands.

The reporting requirements under section 4001 Purpose – Section (3) stipulate that these funds will be used to "facilitate the reduction of wildfire management costs, including through reestablishing natural fire regimes and reducing the risk of uncharacteristic wildfire." Subsection 4(A)(ii) states that projects will "affect wildfire activity and management costs," and Subsection 4(B) states that "the use of forest restoration byproducts can offset treatment costs while benefiting local rural economies and improving forest health." Analyses to verify the potential for attainment of these purposes and objectives can all be met through a combination of cutting edge fire and economics modeling and reporting. However, to meet the wildfire management cost reporting requirements described in Title IV, spatially explicit treatment schedules for each strategy, with at least a coarse estimate of projected implementation timing and costs are mandatory from each proposal team. The proposal requirements sent to Regional Foresters on February 24, 2010 identified multiple topics to be addressed in each proposal. Among others, these requirements included:

**Is there a strategic placement of treatments?**
What types of treatments will occur?
How many acres will be treated and when?
What wildfire behavior is anticipated with current conditions?
How will uncharacteristic wildfire be addressed?
How will natural fire regimes be reestablished and maintained?
What wildfire behavior is anticipated in restored conditions?
How will wildfires be managed in a restored landscape?
Were community wildfire protection plans incorporated?
**What long-term wildfire management cost reductions would occur**?
What value would the removed material have and how would it offset treatment cost?
What federal investments are anticipated within the landscape?

These questions collectively require that each team develop a spatially explicit treatment schedule as part of their proposal. For various reasons, including budget uncertainty, transformation of project planning through NEPA planning and other anticipated realities of planning and implementation, the treatment schedule designed during the proposal may differ from what is eventually implemented. That reality should not prevent teams from strategically planning treatments across the proposal landscape for the full duration of the proposal. Once a treatment schedule is completed, teams can work with agency fire modelers and economists, using our best modeling tools to validate their expectations of risk reduction and cost savings. This process should be used as part of proposal documentation, and also as a means to improve proposals prior to submission.

Teams need to balance the amount of time spent on the various proposal and project requirements (proposal, work plans, and monitoring reports (annual and 5-year)) to meet the identified reporting needs and the needs of collaborative planning and implementation. More time spent on analyses during the proposal phase is likely to lead to more effective and feasible implementation of hazardous fuels reduction strategies that will produce the desired results. By using R-CAT a proposal team can demonstrate that they have adequate capacity to plan and implement a forest landscape restoration strategy with the potential to produce cost savings and risk reduction. If guidance contained in this user's guide is followed, then collaborative proposal teams will demonstrate the ability to incorporate the best available science and scientific application tools in ecological restoration strategies (4003(c)(1)(C)) during the proposal phase.

# Using R-CAT

Given the varying degrees of fire modeling and economic analysis capacity among CFLRP teams, a process and tool package were developed to help standardize the approach of estimating risk reduction and estimated cost savings from land management treatments, while simultaneously allowing teams to flexibly meet requirements of the Act. A standardized approach allows a basis of comparison across proposals and the possibility of aggregating savings estimates for regions with multiple funded CFLRP proposals and the national program. If teams use different methodologies to estimate the anticipated fire program cost savings, then it will be difficult to compare the expected value of the proposed work and the results of the various proposals. The Wildland Fire Risk and Cost Management Tools Package (R-CAT) was developed to address this problem. R-CAT provides teams with a standard approach to plan and design a long-term schedule of fuel and vegetation treatments across their entire proposal area. This first step, developing a spatially explicit treatment schedule is required for the simulation modeling that feeds the economic analysis. The R-CAT Spreadsheet Tool helps teams interface with fire modelers to estimate cost savings from proposed fuel treatment and should allow teams to explore cost savings from different intensities and patterns of vegetation and fuel treatments.

This user's guide helps proposal teams address this need with a consistent approach for a risk management and suppression cost savings estimation process to address the needs identified in the act. When wildland fire program cost analysis is combined with changes in threat levels for identified values at risk from wildfire and estimated decreases in unit costs of implementing ecological restoration treatments over time CFLRP teams will be able to meet Section 4003(c)(4) for their proposals. This R-CAT package may also be useful for the Secretary's five-year reporting needs. Table 1 identifies potential avenues to reduce fire program management costs. It shows how each mechanism can ideally be incorporated through parts of R-CAT and it provides a few alternate means to evaluate how these mechanisms can be quantitatively analyzed.

Table 1: Possible risk reduction and cost savings opportunities that can result from CFLRP hazardous fuels treatments.

| **Cost Category** | **Category** | **Mechanism** | **Recommended R-CAT Evaluation Approach** | **Alternate Methods** |
|---|---|---|---|---|
| Fuel treatment | Net unit costs decrease | Processing demand increases as volume offered spurs processing infrastructure, byproduct value increases, net costs per acre decrease | Show increases in annual net treatment revenues through time in R-CAT Spreadsheet tool | |
| Fuel Treatment | Unit costs decrease | Maintenance slashing and burning replace thinning, net costs per acre decrease | Show reductions in annual net treatment costs through time in R-CAT Spreadsheet tool | |
| Suppression | Small fire costs | Reduced initial attack costs as small  fires become easier to extinguish* | Adjust small fire costs in R-CAT Spreadsheet Tool | |
| Suppression | Large fires costs | New fuel patterns lead to changes in fire behavior and fires sizes are reduced following treatment | Changes in FSim outputs to SCI, captured in R-CAT Spreadsheet Tool | Changes in large fire costs based on expert opinion. |
| Suppression | Large fires costs | New fuel patterns lead to changes in fire behavior near WUI / communities, and fires are less costly to fight | Changes in FSim outputs to SCI, captured in R-CAT Spreadsheet Tool | Changes in large fire costs based on expert opinion. |
| Resource Protection | Large fires costs | New fuel patterns lead to changes in fire behavior near WUI / communities, and fires cause less damage to VAR | Use ArcFuels to demonstrate changes in burn probability and reduced risk, where risk = probability of threat times value at risk. | Use another approach to demonstrate changes in burn probability and reduced risk, where risk = probability of threat times value at risk. |
| Suppression | Large fire costs | New fuel patterns lead to more fire for beneficial use | Use FSim fire intensity information and a GIS exercise with Fire Management Plans to estimate Low, Moderate, and High rate reductions to adjust SCI estimates based on estimates of contiguous area and monitoring: full suppression cost relationships. | Use expert opinion to estimate low, moderate and high percentages and the portion of monitoring costs compared to full suppression in contiguous areas where this will now be possible. |
| Post-fire | Post fire costs | New fuel patterns lead to reduced fire intensity, and create less need for post-fire expenditures | Change the BAER, Rehab and Reforestation Costs in R-CAT Spreadsheet Tool | |

* This logic is the subject of debate and must be well documented for your specific location using examples of recently observed situations.

Appendix R of this document contains detailed R-CAT Spreadsheet Tool instructions that guide the user in what information they need to collect and enter to run the R-CAT spreadsheet tool. This user’s guide explains the functionality and methodology of R-CAT as applied for CFLRP purposes. Future versions of R-CAT may provide a link to the Cohesive Strategy modeling that will be conducted at the Regional/Geographic Area Coordination Center scale as mandated by the FLAME Act of 2009; allowing CFLRP teams to place their body of work into the context of their larger landscape. This user guide will be updated as those versions are made available.

Appendix Z is a discussion of the FSim and SCI modeling approach used to support R-CAT for the Deschutes National Forest maximum treatment hypothetical example.

# Methodology

Each annual request for CFLRP proposals contains a list of documentation required for each proposal. For the required proposal elements covered by R-CAT your team may wish to coordinate with fire and economic modeling support personnel. You will also want that coordination to be integrated with the rest of your proposal efforts to ensure that all your analyses are aligned and reliant on the same proposal content. R-CAT is a modeling tool package used in a process to assist teams in their design of fuel treatment and vegetation management schedules that enhance the protection of values at risk from wildland fire (although not explicitly included in the R-CAT spreadsheet tool, added protection of values at risk can be listed in Wildfire section of your proposal) and reduce fire program management costs (including treatment, suppression and post-fire costs). To estimate changes in anticipated costs, R-CAT uses a macro-enabled Microsoft Excel workbook (.xlsm) as the interface between user inputs and results from existing fire models. It was designed to represent the Forest Service’s best estimates of changes in fire management program costs using the best available modeling tools. To accomplish these goals the analyst uses the R-CAT Spreadsheet Tool with results from fire behavior simulation modeling (ideally FSim) with economic information about how treatments will change several fire program management costs (ideally a regression-based econometric fire cost model such as the Stratified Cost Index) with some historical cost figures from the proposal area. However, it can also be used with less rigorous cost estimates. The individual worksheets in the Spreadsheet Tool contain the formulas that provide results in the form of discounted total expectations for changes in fire management program costs over the life of the proposal treatments. R-CAT was designed to streamline these estimation processes to help CFLRP teams prepare proposals and evaluate anticipated cost savings under one or more treatment and funding scenarios. The goal for these tools is to assist teams with these challenging tasks while providing a standard approach at the proposal stage, which can also be used in a retrospective evaluation.

A summary of the R-CAT tasks is provided below, followed by more detailed discussions and instructions for obtaining and using R-CAT and reporting your results.

## R-CAT for CFLRP Proposals - Summary of Tasks

1: Construct spatially explicit current fuel model and fire behavior maps of your proposal area
2: Construct spatially explicit fuel treatment schedule with maps of fully treated proposal area, timing, expected revenue from and costs of treatments, as well as maps of treated fuel models and fire behavior.
3: **Estimate expected annual fire season <u>acreage</u> before and after treatments for your proposal area.** Ideally, this means that you estimate median and variance of expected annual large fire results by simulating fire seasons for your current and fully treated landscape using fire modeling.
4: **Estimate expected fire season <u>costs</u> before and after treatments for your proposal area.** Ideally, estimate median and variance of expected large fire costs per fire season from the simulations.
5: Enter fuel treatment revenues and costs, small fire costs, large fire costs, reductions in costs associated with re-establishing natural fire regimes and BAER/Rehabilitation/Reforestation costs into R-CAT spreadsheet tool.
Note: entering small fire costs, each of the post-fire costs and beneficial use estimates are optional in this step.
6: Communicate findings to your collaborative and adjust treatment schedules as needed (by returning to Task 2) or submit results in your proposal.
7 (Optional): Re-estimate your results based on experienced costs after 5, 10, and 15 years as part of monitoring.

## Detailed Task Descriptions

### *Task 1: Construct spatially explicit current fuel maps of your proposal area*

The overall methodology requires that you first work with your collaborative to describe and map the current vegetation and fuels for your entire proposal area. This should include the entire tapestry of ownership and may be done using LANDFIRE (www.landfire.gov) or other locally-preferred data. Whatever the data source it needs to be checked and verified by the collaborative for accuracy of current conditions.

As part of this step you should develop a description of the project area current (baseline) fire behavior conditions, and values-at-risk. Descriptions should include but are not limited to the following:

- Fire history for surrounding area (sizes, frequency, causes, and management cost history for the local national forest(s) and adjoining lands) using available databases.
- Optional: Fire Regime Condition Class (LANDFIRE FRCC)

➢ Current condition static FlamMap fire behavior maps.

  - Inputs: Pre-treatment landscape files (LCPs) created from LANDFIRE or other sources and weather parameters.
  - Outputs: flame length and fire type descriptions.
  - Alternatively, fire probability and burn severity maps will soon be available through the Fire Program Analysis (FPA)

- Values-at-Risk (VAR). Describe the potential extent and magnitude of values and resources at risk in the proposal area using overlays with fire behavior maps and/or other descriptive means. Suggested sources: NFS units in combination with Wildland Fire Decision Support System staff supported critical infrastructure maps, natural and cultural resource maps and fire type VAR summary word reports, or additional site-specific VAR information). Potential VARs for overlays and qualitative description include the following:
  - Local Community Wildfire Protection Plans (CWPPs) (4003 b(3)H)
    - Wildland Urban Interface (WUI)
    - Numbers of properties, residences, utilities, infrastructure, etc.
  - Old growth (4003 b(1)D)
  - Water quality/watershed function (4003 b(3)C)
  - Areas at risk to invasion from exotic species (4003 b(3)D)
  - Road and trail systems (4003 b(3)E)
  - Threatened and endangered fish and wildlife habitat (4003 b(3)B)
  - Other significant VAR for the proposal area

While it is not imperative, teams are highly encouraged to use ArcFuels (www.fs.fed.us/wwetac/arcfuels) to accomplish the creation of the LCPs and baseline fire modeling outlined in Task 1. This will set you on a path for a smooth analysis in the later R-CAT tasks. ArcFuels is supported by the Western Wildlands Environmental Threat Assessment Center (WWETAC) and is a library of ArcGIS macros that facilitates the application of models like FlamMap and FVS for developing and testing fuel treatment scenarios at the stand and landscape scales. The macros provide data linkages between fire models and desktop database and spreadsheet software. ArcFuels automates much of pre- and post processing of data for fire behavior modeling and to design fuel treatment projects, allowing for rapid design and evaluation of fuel management scenarios. The library is distributed as an ArcMap project file (.mxd) and is implemented with a custom toolbar on the ArcMap interface.

## *Task 2: Construct spatially explicit fuel treatment schedule with maps of fully treated proposal area, timing and costs of treatments.*

In consultation with your collaborative you should discuss the types of treatments you propose for the implementation and the characteristics of target locations. You should discuss the expected transition in surface fuel models and canopy characteristics that different treatment types are expected to achieve in various vegetation types. By infusing information about the anticipated effectiveness of treatments to change the pattern of fuels (and ultimately fire behavior) across your proposal landscape and by mapping VARs, you should be able to begin to discuss how your plan will potentially reduce fire program management costs and reduce documented wildland fire threats. You should discuss and map the spatial and temporal distribution of treatments over the life of the proposal given expected budgets and planning requirements. You should discuss the longevity of effectiveness for each of your proposed treatments. All these steps will help you prepare one or more renderings of the treated landscape at the end of your proposal implementation. ArcFuels can be especially helpful during this phase of the analysis; however, there are other options for completing this step. As you work with your collaborative, you will need to address the following topics:

- Budget for implementing and monitoring treatments broken into funding sources, Federal and non-Federal (this will also be in separate section of proposal where match is described etc.)
- Treatment prescription descriptions and unit costs for project area
- Samples of stand-level treatment effectiveness (4003 b(3)A) using FVS-FFE, BEHAVE, NEXUS, etc., to demonstrate the potential for proposed treatments to change fire behavior (e.g., percent reduction in flame length).
- Anticipated suppression costs and cost savings - qualitatively project why cost savings will occur (e.g., less intense fire, smaller fires, less rehabilitation and Burned Area Emergency Response (BAER) costs, cheaper management options ) and how costs will change (4003 b(4)A). Describe range of costs for proposal area based on historical fire data, if any.
- Anticipated decrease in the NFS unit costs of implementing ecological restoration treatments over time (4003 b(4)B).
- Describe how best-available science and scientific application tools (Sec 4003 b(1)C) will be used to identify areas/units targeted for treatment.
- Describe the potential for revenue and cost-offsets (Sec 4003 b(1)B(iv)):
    - Projections of conventional merchantable material,
    - Description of projected small diameter and woody biomass byproducts as sources of revenue. Refer to Healthy Forest Restoration Act, or locally applicable definitions (e.g., Sierra Nevada Forest Plan, Northwest Forest Plan),
    - Existing/future infrastructure for utilizing byproducts, and
    - Local markets and price conditions and trends.
- Treatment plan specifics:
    - General treatment type - mechanical thinning (including type of machinery), prescribed fire, or combinations
    - Basal area targets
    - Specific elements that will be contracted and those done with FS personnel
    - Design criteria and best management practice requirements
    - Best estimate of implementation timing
        - Take into consideration recent history of treatment implementation in the project area.
        - Reveal potential constraints on timing (e.g., acceptable prescribed fire burning conditions, NEPA planning capability, etc.)

Much of the work to supply this information would normally be conducted in the process of planning large-scale fuel treatment proposals anyway. Fortunately, many of the same modeling tools used to locate treatments and evaluate how well-planned activities meet multiple ecosystem management objectives also produce outputs that can be used to support cost and economic impact modeling needed to address CFLRP performance reporting requirements. Without this important information, which can only be produced by proposal teams, your proposal would rely on speculation and conjecture to fulfill Title IV requirements.

Efforts should be made in Step 2, to use available fire models to learn about expected fire behaviors sufficiently to narrow the number of alternate treatment schedules down to a manageable number for your fire modeler at this stage. In addition documentation of how and why surface fuel models and canopy characteristics were modified to represent treatments is required. This documentation can include:

- In most cases FVS-FFE or expert knowledge based on field observations will be used to estimate the changes following implementation of treatments.
- Conversions will vary based on antecedent vegetation conditions so teams will need to document expected conversions for all prescription/condition combinations.
- When possible, teams should rely on existing FVS keyword component files, and attempt to substantiate LCP conversions using peer reviewed literature.

Treatment and activity schedules should have accompanying estimates of treatment costs and revenues spread realistically over the duration of proposal implementation. Treatment costs will need to be calculated as accurately as possible to improve the quality of the wildfire program cost analysis. Cost estimates are derived using many different techniques across the country.

- We recommend using FVS-FFE to get an understanding of the cut tree lists expected from each combination of treatment and existing conditions.
- Many people find the Fuel Reduction Cost Simulator (www.fs.fed.us/pnw/data/frcs/frcs.shtml) is useful.
- You can obtain unit costs for many ecosystem restoration activities by working with implementation coordinators and planning staffs in your project area
- You will want to validate your cost estimates
  - Compare cost estimates to regional averages
  - Explain special circumstances that cause your cost estimates to differ
- Reduce your costs by projected revenues that are byproducts of your treatments.
  - Run appraisals to estimate advertised and predicted high bids for conventional wood products.
    - Apply local adjustments for processing overrun / underrun, acknowledging that you will not have cruise information for most of the projects that your strategy work plan will comprise
  - As a result of your plans to utilize small diameter material and biomass with existing or planned infrastructure, you should have an estimate of the costs or revenues associated with this part of your work plan. You should include this in your cost estimates in a manner that can be understood by the modeling support team.

## *Task 3: Estimate expected annual fire season <u>acreage</u> before and after treatments for your proposal area. Ideally, this means that you estimate median and variance of expected annual large fire results by simulating fire seasons for your current and fully treated landscape using fire modeling.*

Once you have prepared your current and fully treated landscape(s) you are ready to work with agency fire modelers to model the "large fire" behavior expected under each scenario. The most desirable way to do this is to use local weather station data and historical fire ignition data, running thousands of simulated fire seasons. There are several platforms that can be used to conduct this modeling, but the recommended approach is to work with fire modelers to use the Large Fire Simulator (FSim, see details about FSim below). This can be accomplished by agency personnel at WWETAC, or the Missoula Fire Lab, although each region will soon have this capability as part of the Cohesive Strategy mandated by the FLAME Act of 2009.

The process described above for the untreated landscape would be repeated with the treated landscape(s). Simulations will use the same set of fire ignition location / weather condition combinations allowing for direct fire season comparisons between pre- and post-treatment landscape(s). By running the two or more fuel patterns for your landscape through FSim, results are produced that allow teams to use R-CAT to estimate how fire program costs compare under multiple schedules and use ArcFuels to evaluate the degree to which risk to identified values would change.

**FSim**

FSim (Finney 2007, unpublished report, available at: www.fpa.nifc.gov/Library/Docs/Science/FPA_SimulationPrototype_0705.pdf) is a landscape-level fire modeling system that utilizes the minimum travel time spread algorithm (Finney 2002) similar to FlamMap/FARSITE to simulate thousands of large fires based on daily and seasonal weather. Outputs include information pertaining to the individual ignitions as well as annualized burn probability and fire intensity distributions derived from the ignitions which can be used to understand the effect of fuels (and therefore fuel treatments) and topography on large fire growth. Because FSim simulates fire growth at the landscape-level it is possible to understand the effects of fuel treatments within the treatments as well as offsite on VARs.

Specifically FSim uses historic fire weather information to create artificial fire seasons (up to 100,000) which correlate the energy release component (ERC) to large fire occurrence. Fires are then ignited daily and simulated using the simulated fire season data from the ignition date through the remainder of the season or until containment is achieved. Containment is predicted based on a suppression model (Finney et al. 2009) which utilizes historic containment probabilities and ERC values which are correlated to high and low fire spread. FSim has the ability to replicate ignition locations and weather parameters which allows for a direct comparison among varying treatment alternatives or time periods.

*FSim outputs relating to SCI and risk assessment*

FSim outputs will provide two products, 1) inputs needed to calculate large fire suppression costs using the stratified cost index (SCI) model and 2) a quantitative assessment of change in risk to VARs. The fire environment inputs for SCI will include: ignition locations, fire intensity level and energy release component (ERC), in terms of cumulative frequency, for the first burning period, and the fire size for the duration of the simulation. Fire intensity level is a categorical valued based on expected flame length (Ager et al., in prep); the fire intensity levels are associated with 0-2 ft, 2-4 ft, 4-6 ft, 6-8 ft, 8-12 ft, and greater than 12 ft flame length categories. FSim outputs may also be used to estimate cost reductions from changes in response strategies, a.k.a. increased beneficial use following fuel treatments. If you have reason to believe that following implementation of your treatments you will be able to change the response strategies and associated costs of fighting fires you can use that information from FSim in addition to what is needed for SCI. You should consider at what point in the implementation of your treatment schedule that this change might occur. You have opportunity to estimate a low, moderate, and high percent reduction in the area where large fires could be monitored instead of requiring full suppression. These are areas where large fire cost savings and post fire costs savings could occur once you have returned the landscape to natural fire regimes and you have substantially reduced the potential for catastrophic or ecologically undesirable fire. To derive these estimates, you could use fire intensity information from FSim in a GIS exercise where you evaluate what aerial proportion of your proposal area could benefit from this change in management from full suppression to monitoring fire for beneficial use. This requires that you reference a valid fire management plan and consult your Fire Management Officer. At this point R-CAT assigns these portions of the savings associated with monitoring in place of full suppression for the entire analysis period. If you would like to change this calculation design it will involve some adjustments in default the calculations.

To assess relative change in risk from treatment, pre- and post-treatment vectors of marginal burn probabilities and fire lists are analyzed using ArcFuels. The “Risk” tab in ArcFuels automates the calculations required to summarize burn probabilities, fire size, and conditional flame length. These values can be summarized for any spatially explicit area of interest, such as values-at-risk or land ownership. Burn probability profiles, and scatter plots of burn probability vs. conditional flame length and burn probability vs. fire size can be created. The relative change in risk due to treatments can be shown with these graphics. Relative risk and odds ratios can also be calculated to quantitatively describe changes in risk from treatment.

## *Task 4: Estimate expected fire season costs before and after treatments for your proposal area. Ideally, you will estimate median and variance of expected large fire costs per fire season from the FSim simulations modeled with SCI.*

The focus of the R-CAT Spreadsheet Tool is to estimate the change in USFS fire program management costs. It may be desirable for your collaborative to estimate the expected change in costs for all partners, especially in areas with mixed ownership with only a slight majority of NFS lands in the landscape greater than 50,000 acres. Since the focus is NFS costs, if you are planning to evaluate all costs, it is suggested that you use two versions of the analysis; one for NFS costs only, the other for all costs.

Large fire costs represent the majority of fire costs for many national forests. As a result, they represent a large component of the cost savings estimation in the R-CAT Spreadsheet Tool. The most defensible system to estimate fire costs for large fires was developed in FY2006 by the Rocky Mountain Research Station and it is called the Stratified Cost Index (SCI - Gebert et al 2006).

The SCI is simply a set of regression equations developed to estimate suppression expenditures on individual large wildland fires (fires greater than 300 acres). That is, characteristics of the fire, such as fire size, the fire environment (slope, aspect, energy release component, fuel model, etc), housing values within proximity to the fire, and geographic area are used in a statistical model to come up with an estimate of the cost of the fire. Currently, there are six regression equations incorporated into WFDSS -- two Forest Service models (one for the western U.S. and one for the eastern U.S.) and four DOI model (one for each agency, BLM, FWS, NOS and BIA). These cost models incorporated into WFDSS are built using historic information on suppression expenditures and fire characteristics, using data for fires occurring in FYs 2005-2009 from all geographic areas. The independent variables (the fire characteristics used to predict cost) vary somewhat by model (FS west, FS east, DOI). **The models also include a regional variable that accounts for differing costs across geographic areas (defined as either FS regions or Geographic Area Coordination Centers).** The dependent variable (what we are trying to predict) in each of the models is suppression expenditures per acre. When used in combination with acreage projections from FSim, these estimates can be used to calculate estimated costs per fire or per fire season. These cost estimates reflect expenditures by all federal agencies (FS and DOI) on the fire or fire season in question. They do not include state expenditures unless those expenditures are already captured in the federal accounting system. The FS regression models were developed using data on fires where the FS was the protection agency of record. Similarly, the DOI model was built using data on fires where one of the DOI agencies was the protection agency of record.

The process required for the application of SCI in R-CAT requires the step of acquiring attribute information used in the cost regression analysis for each fire location ignition location. Since the ignition locations are held constant, these attributes are constant for both the untreated and treated landscapes, and therefore this step only needs to occur once, which is good, because this represents one of the processing bottlenecks in the R-CAT package**. It is important to schedule roughly 3 weeks to allow IBM to retrieve the attributes used in SCI for each ignition point used in the FSim modeling for your project area.** In the future the Forest Service may be able to support teams with a quicker turnaround. Once all fire costs are estimated for each season, a distribution of fire season costs from tens of thousands of simulated seasons is prepared. The fires from the pre and post-treatment simulations that fell below the predictive range of SCI (<300ac) and those greater than any fire expected in your area (variable) should be removed prior to estimating median fire season costs for insertion into R-CAT spreadsheet tool.

There may be other ways to estimate large fire costs per season for your proposal area, such as averaging large fire costs (Class E-G) from recent fire seasons in the proposal landscape, but a challenge teams will face is to state, explain and quantify how suppression costs would change following fuel treatment. The SCI helps meet this challenge, and although there are several limitations which have been identified for this analysis tool, it represent the best available science in its ability to use historical data to predict how fire season costs for large fires would change following treatments.

Also note that during this step, it is recommended that the fire modeler and the CFLRP team compare large fire size distributions using an appropriate statistical test to ascertain whether a significant difference exists between pre and post fire size and cost distributions. Have your SCI analyst help you with this task as it is not automatically performed. If results show no statistical difference in project fire season costs this information should accompany the reporting of your R-CAT results.

## *Task 5: Enter treatment revenues and costs, small fire costs, large fire costs, reductions in costs associated with re-establishing natural fire regimes and BAER/Rehabilitation/Reforestation costs into R-CAT spreadsheet tool.*

R-CAT has been set up for use by analysts with varying degrees of economic expertise. The most important component of using the tool is modeling and inputting user data. If data is input incorrectly the results will not be representative of economic consequences that may occur with the fuel treatment and restoration activities. This section explains the mechanical operation of the tool and interpretation of the results. The theoretical underpinnings of the models are not discussed in detail because they are not relevant for the functionality of the tool. For a detailed discussion of these tools please see the ArcFuels Users Guide, and contact RMRS modelers to learn more about FSim and SCI since user's manuals do not currently exist for these two tools.

**The R-CAT Spreadsheet Tool**

The R-CAT Spreadsheet Tool is a macro-enabled Microsoft Excel workbook that contains three worksheets required for estimating anticipated cost savings, documenting inputs and reporting results.

The worksheets of greatest interest to the average user are titled "Table 1. Fire Cost Analysis" and "R-CAT Results Summary." The R-CAT Spreadsheet Tool can be run using only these two worksheets. The "Table 1. Fire Cost Analysis" worksheet is where the user will input all data associated with fuel treatment and fire management activities (includes all vegetation treatments that will affect standing or downed fuels). The "R-CAT Results Summary" worksheet is where the output is reported. This worksheet requires no data entry, and only serves as the interface for reporting results within the appropriate context of assumptions and limitations. The summary table may be cut and paste directly into CFLRP proposals to meet the requirement of estimating the anticipated fire management program cost savings that would result from implementing the restoration strategy. The worksheet tab title "R-CAT Documentation" is where users enter information needed to explain, justify or substantiate the analysis. The remainder of this section goes into greater detail on the mechanics of these three worksheets.

### *Enter Project Details into Appendix R and the R-CAT Spreadsheet Tool*

*Download R-CAT Spreadsheet Tool from the following website:*

http://www.fs.fed.us/restoration/CFLR/submittingproposals.shtml#tools

**This is a macro enabled Excel Workbook file, the first thing you need to do is enable the macros. Because there are no numbers in the blank version when you start, you will see several cell that have an error message in them, #DIV/O!. Do not panic! These will automatically be replaced with results when you enter the needed information.**

You will likely see a Security Warning "Macros have been disabled". If so, click on the "Options" button, select "Enable this content", and click "OK". If you do not see a security warning, you will need to change Excel's macro security settings. On the Excel ribbon, click "Developer". To the left, select "Macro Settings", then "Macro Security" and choose "Disable all macros with notification." Close and reopen R-CAT. You should see the Security Warning near the top of the screen. Then enable this content.

The tool was constructed so that the obvious mechanisms for potential costs savings (Table 1) are all incorporated into your analysis. For those teams interested in generating defensible analyses, the R-CAT Spreadsheet tool requires the bulk of the work to be completed by agency fire and economic analysts.  Other teams may decide to rely more on expert opinion, substantiated through recent experiences. In either case, your team's R-CAT analyst needs to enter some information at the beginning of the process to adjust the structure of the cost estimation table. Fields found in the worksheet that need to be addressed are listed below:

Proposal name
Treatment start year and end year period (two pull down menus)
Average treatment effectiveness duration (pull down menu)

*After entering these numbers, macros in the R-CAT spreadsheet tool automatically format your spreadsheet, modifying the table to prepare for calculations.*

Once you enter the remaining information your estimated cost savings (or additional costs if parentheses appear) will be automatically calculated. These additional input needs include:

Total proposal area acreage
Total acres proposed for treatment
Average fuel treatment revenues per acre or actual treatment revenues per year
Average fuel treatment cost per acre or actual treatment costs per year
Average annual small fire (< 300 ac., Fire Classes A-D) costs
Average annual Burned Area Emergency Response (BAER), rehabilitation and reforestation costs
Percent of the proposal landscape where suppression can be replaced by less expensive beneficial fire use monitoring, and the proportion of monitoring costs compared to full suppression costs.

*Some variables and calculations are locked for the user. Examples include the discount rate, which is set to the 4% rate mandated by OPM in Circular A-94.*
If you believe there are additional opportunities for cost savings that are outside the current R-CAT Spreadsheet Tool, and they are justifiable based on historical experience or peer-reviewed literature, work with your modeling support contact to include these calculations **Do not simply make adjustments to the results without first consulting a fire modeler or economist assigned to support R-CAT, as you risk the credibility of the results. You will need to qualify the results with your logic on the R-CAT Documentation tab in the Workbook, and while this is acceptable, do not manipulate the numbers without adequate justification.**

## *Task 6: Communicate findings to your collaborative and adjust treatment schedules as needed, submit results in your proposal.*

After completing the R-CAT process, you will have one, or possibly more than one treatment schedule(s), accompanied by changes in threat/risk to values identified in Task 1. You will also have an estimate of the change in fire program management costs for the full duration of the proposal, as well as a sense of the annual changes in costs. Only these results found in the "Results – Cost Savings" tab of the spreadsheet tool should be shared. For example, although cost savings are theoretically accurate, wildfire expenditures used in these calculations may be different than true amounts if analyses include spatial buffers to model fires near to, yet outside of the project area. Therefore we recommend only savings, not total expenditures, should be reported.

Admittedly, the analysis techniques in R-CAT are sophisticated and the complexity of the presentation of these results should be geared to the audience. Some audiences will be very critical of your projections, emphasizing the need for you to be transparent and well-documented in your communications. Here are some reporting topics to consider.

**Reporting sources, models and limitations with your results**

***Apportioned cost savings based on percent treatment effectiveness***

The new projected annual large fire costs are estimated for the year when all treatments are completed. Estimated future large fire costs for the fully treated landscape are subtracted from the expected fire costs associated with no treatment to reveal potential wildfire management cost savings, or avoided costs in the project area attributable to the treatments. A portion of this savings, which matches the portion of total acres treated/cumulatively effective by year is then credited to each year before and after full completion of the treatment schedule. The length of time this cost savings is expected will depend on the site-specific treatment effectiveness duration. Using expert opinion or modeling tools such as FVS-FFE, this savings is projected into the future where the appropriate portion of costs savings persists as long as the effects of each treatment persists. This cost savings is then compared to the cost of the treatments to conduct the complete cost analysis. While using the synergistic effects of having the full treatment schedule modeled instead of modeling treatments that persist for each individual year may overstate the costs savings slightly, more intensive modeling is not supportable at this point. This is because modeling fuel treatments for each year would be too onerous for the fire modelers working with limited access to the supercomputers, and the uncertainty surrounding actual implementation locations and timing does not warrant this extra modeling.

***Fire growth as the driver of fire cost***

No matter what fire models are used as inputs to the economic analysis, there is a need to discuss how well these models represent fire behavior changes in your particular landscape. For example, treatments may effectively change fire size in some areas and that might be expected to reduce suppression costs. This can typically be seen through reduced annual cost expectations coming from the SCI analysis of FSim results. However, in other areas, changes in fire sizes might not be expected as much as changes in the types of fire behavior following treatment. In some cases, grass or woody shrub understory may prevent over story treatments from changing expected fire sizes. In these cases the economic analysis may not show much change in suppression costs following treatment, but you can demonstrate anticipated wildfire management cost savings through expected reductions in emergency stabilization funding, long-term rehabilitation and reforestation in the R-CAT Spreadsheet Tool. Inputs should also reflect assumptions about changes in these costs if more beneficial use fire is expected and included in your analysis. No matter what you include in the economic analysis, it is important to frame and justify these estimates. If you feel that the modeling over represents changes expected in fire size you should convey that with the results to the audience. Quantitative analysis from your project area suggesting the cost saving value of fuel treatments is desirable to support these estimates, but theoretically based estimates of changes to costs may also be warranted based on appropriate interpretation from similar forest types with similar fire regimes.

***Accuracy of fire cost data and known problems with historical cost reporting***
Fire costs are estimated based on location. It should be possible to delineate the boundary of your proposal area and isolate all the Class A-D fires that occurred in the past 10 years to estimate average annual, pre-treatment, costs for Appendix R and the R-CAT Spreadsheet Tool. Estimating the costs of larger fires, Classes E-G may present problems as these fires sometimes initiate outside or burn outside the proposal boundary and therefore the cost accounting is not as clean.

Beyond geography, there are also issues of joint fire cost accounting (especially with complexes), and shared resources counted by single large fires. Some proposal teams may have difficulty estimating costs due to direct protection authority boundaries in their proposal area. You are reminded to seek out the end of the year breakdowns for these costs.

Longer term costs outside the P code realm, also present some challenges. BAER teams sometimes request $2^{nd}$ and $3^{rd}$ year funding based on monitoring, and NF3 and reforestation costs that extend several years beyond large fires can complicate cost accounting. You are encouraged to explore these topics and document all of your inputs well.

**Large Fire Simulator (FSim)**
*Accuracy of fire modeling*
Like any model FSim is a representation of reality; it relies on BEHAVE PLUS modeling logic and is part of the FARSITE modeling family. Some studies suggest these models do not accurately model fire behavior and spread. Forest example, Cruz and Alexander (2010) suggested that these models chronically under predict crown fire behavior in conifer forests of western North America. We encourage people using R-CAT to become familiar with the recent literature describing applications and critiques of these models to improve their ability to explain the modeling processes and its limitations. However, these models are currently being used in the Wildland Fire Decision Support System, Fire Planning Analysis (FPA), and are proposed for the Cohesive Strategy modeling mandated by the FLAME Act of 2009, and thus represent the best available science.

**Stratified Cost Index (SCI)**
*Non-spatial aspect of SCI*
Currently SCI analysis relies on a single point location for each fire. It is acknowledged that fire characteristics can change rapidly as fires transition between fuel types, aspects, etc. This weakness is being addressed by transitioning SCI to a perimeter-based approach, more representative of the spatial description of each fire. If these changes are completed in the near future, SCI analysis may improve.

**Using statistical testing to validate the largest component of costs (pre-treatment versus post-treatment projected fire season cost distributions)**
Although point estimates (e.g., medians) from thousands of simulations for the untreated and treated landscape are a standard summary statistic and are a defensible representation of the fire season results, without confirming a statistical difference between annual large fire season costs from the untreated and treated landscape the computations to estimate annual cost savings may be

without sound basis. Some debate exists about whether tens of thousands of simulations represent a population or a sample. Therefore, to increase the analyst’s confidence in the results from SCI, the difference in fire season cost distributions can be tested using appropriate techniques.

### *Task 7: Re-estimate your results based on experienced revenues and costs after 5, 10, and 15 years as part of monitoring.*

This task is optional and can be a nice way to connect your planning with your monitoring. You simply replace the projected costs and acres with experienced acres, revenues and costs in the Spreadsheet Tool and analyze the new costs compared with what was projected under no treatment.

# Fire and Economic Modeling Support – Who Can Help Us?

There is a demonstration R-CAT Spreadsheet, displaying a hypothetical maximum treatment example for the Deschutes National Forest. This file (1-7-11 R-CAT Spreadsheet Tool_Max Treat DNF.xlsm) can also be found at:

http://www.fs.fed.us/restoration/CFLR/submittingproposals.shtml#tools

In order to facilitate communication and execution of the steps, it is recommended that the leader of each CFLRP proposal team assign R-CAT responsibilities to one FS individual on their team. Your next step is to secure the support from WWETAC, or other agency personnel capable of FSim and SCI modeling and one of the Forest Service economists to perform fire and econometric modeling. There are a handful of people currently employed by the agency that could provide this support. The analysts require experience and competence with GIS, advanced fire modeling, economics, and access to limited multiprocessing computers.

The following support network is needed to conduct the full R-CAT analyses:

ArcFuels capable CFLRP team staff, or competent fire and fuels staff with GIS skills and an ArcFuels trainer, FSim Modeler, SCI Pre processer, SCI post processer, R-CAT spreadsheet tool analyst.

R-CAT is supported by the Service-wide fire and economics community. You may contact a NFS economist, or anyone on the development team, but please realize that Headquarters has not provided these positions with any special funding or clear prioritization to support R-CAT. Any personnel supporting your team will work part-time on CFLRP work, helping coordinate the generation and transmission of needed modeling data and conducting fire simulations and SCI analyses which lead to overall fire program cost analysis. An economist can help review your fire program costs analysis.

Northern Region, Ecosystem Assessment and Planning, National Forest System
Keith Stockmann (kstockmann@fs.fed.us) Economist
Krista Gebert (kgebert@fs.fedus) Regional Economist, SCI specialist

Western Wildlands Environmental Threat Assessment Center (WWETAC)
Alan Ager (aager@fs.fed.us) Operatins Research Analyst
Nicole Vaillant (nvaillant@fs.fed.us) Fire Ecologist, FSim Specialist

Rocky Mountain Research Station (RMRS)
Matthew Thompson (mpthompson02@fs.fed.us) Research Forester, SCI specialist
Dave Calkin (dcalkin@fs.fed.us) Research Forester, WFDSS Specialist

Washington Office, Ecosystem Management Coordination
Chris Miller (cjmiller@fs.fed.us) Economist

**Logistical considerations for modeling support**
No direction has been given to modeling team member supervisors, emphasizing the strategic importance of having this personnel dedicated to **part-time** support of CFLRP analyses, with an on-call level of commitment. Therefore, supervisors will need to work with the selected FS personnel to balance other priority work, to ensure adequate responsiveness to CFLRP proposal needs. Supervisors may also need to authorize overtime/comp time as needed. In some cases, funding may be needed to obtain modeling support team through specific a job code and override.

# Perspectives on the R-CAT Analysis Procedures

**A new approach**
Although this type of cost analysis has never been conducted, we see no better options. If you plan to spend this money, and you expect Congress to ask the Forest Service to be accountable for the reporting requirements we feel this is the best path forward. We feel that this state-of-the-art modeling will be able to meet the needs identified in Title IV.

**Arduous demands so early in the planning**
We realize that we are asking for high quality outputs from the proposal teams early on during the proposal phase. This is really the only way we can envision successful reporting as stipulated by the law. We realize that different areas of the nation have different skill sets available, and we tried to retain as much flexibility as we could for teams while still providing enough consistency to allow aggregation of program results to meet the letter of the law.

**Program management costs relative to program management benefits (avoided costs)**
While wildfire management costs savings are important, without specific consideration of the values protected and enhanced (including private, and public resources) these treatments may end up appearing to cost more than any wildfire program savings. In other words, not all projects will show a net financial cost savings with the analysis procedures we suggest. However, we feel that if we consider all the economic costs and benefits, many will be worthwhile projects. But we must be at least able to demonstrate that benefits exceed costs. This would be especially difficult if the full group of ecosystem restoration activity costs were included, because many of the

benefits we expect from these activities are non-market in nature and are extremely difficult to quantify. That explains why we have proposed inclusion of only the costs associated with vegetation treatments designed to protect resources from wildfire and reduce fire costs in R-CAT and then relying other proposal requirements and on your annual performance reports, to report the multiple facets of each proposal without taking the contentious step of monetizing non-market benefits. Many of these non-market benefits will come in the form of reductions in expected damage. Analysis options in this vein would rely heavily on risk analysis, with tools like ArcFuels, burn probability maps from FSim, and values at risk mapping to justify treatments.

# Deviations from R-CAT

The purpose of providing R-CAT to all the CFLRP proposal teams is to help them meet the requirements of Title IV in an efficient and defensible manner. R-CAT also helps the agency modeling staff, supporting all the teams, use standard and repeatable analysis techniques. It helps the advisory panel compare results based on the same methodology and it helps the USDA provide regional and national summaries of the program, by aggregating savings results for more than one proposal. These are strong arguments for requiring that all teams apply the same methodology. However, when resources on a team or support personnel cannot meet the RFP deadlines some alternatives may exist to meet the spirit of the act, to demonstrate anticipated costs savings. Caution is advised when substituting alternative methods to estimate pre and post treatment costs outside the defensible system that R-CAT provides. Depending on the quality of the justification for substitute tools and their results proposals may be found less than adequate by the advisory panel. In other words, try your best to follow the R-CAT system, and secure fire and economic modeling support early in the process to give your team the best chance possible to complete the analysis, use the results to review you proposed treatment schedule and possibly make adjustments so that what you propose can be verified to hold potential for risk reduction and costs savings. If none of these desirable outcomes are expected after implementation of your treatments, the proposal will need to justify the projected benefits expected to address the other purposes of the act, and explain why those override expected cost consistency or increases.

# Relationship of Originally Suggested Economic Analysis Procedures and Templates and Appendix B (Stockmann et al. 2009) with R-CAT

To facilitate the level of analysis specified in Title IV, a team of fire modelers from the Rocky Mountain Research Station and the Western Wildlands Environmental Threat Assessment Center met with economists from the National Forest System in June 2009. Analysis procedures capable of meeting the intent of Title IV were crafted. A draft document and its attachments were designed and presented to explain analysis procedures and templates to the advisory panel and proposal teams. This document helped the headquarters Forest Management staff evaluate their options in light of the need to provide guidance to proposal teams. Given the short time period provided in the original RFP, teams were not required to conduct R-CAT analyses for the first round of proposals. However, R-CAT is a requirement for all CFLRP proposals in FY2011 and beyond.

**R-CAT supersedes the guidance originally posted on the CFLRP website and now applies to all proposal teams.**

# Integration of R-CAT with the Treatments for Restoration Economic Analysis Tool (TREAT) economic impact tool and other items listed in the request for proposals.

The requests for proposals for CFLRP will likely evolve in the future. Therefore it is advised that each team assign a person to review R-CAT and look for opportunities to coordinate the tasks outlined here with the other proposal requirements early in the proposal effort.

The proposal needs to present information about the employment and labor income contributions expected through the CFLR fund expenditures for each proposal. The TREAT tool was designed to convert expected expenditures, government full time equivalents and wood products harvest and processing expectations into estimates of employment and labor income to handle this part of the economics requirements for each team during the proposal, work plan and annual monitoring.

Note that the fuel treatment costs and expected treatment byproduct revenues used in R-CAT should correspond to those included as the CFLR Fund used now in the TREAT modeling, in addition to other expenditures used to match fund amounts and implement the fuel treatments included in the full landscape strategy. The economist supporting R-CAT may also coach teams on how to properly use the product estimates used here to estimate net treatment costs into the TREAT economic impact spreadsheet tool to estimate direct and multiplier economic impacts associated with proposals, annual reports and work plans.

# Appendix R: R-CAT Instructions

*Customizing Your R-CAT Spreadsheet Tool to Your Proposal and Running the Numbers*

## Enabling Macros

You will likely see a Security Warning "Macros have been disabled". If so, click on the "Options" button, select "Enable this content", and click "OK". If you do not see a security warning, you will need to change Excel's macro security settings. On the Excel ribbon, click "Developer". To the left, select "Macro Settings", then "Macro Security" and choose "Disable all macros with notification." Close and reopen R-CAT. You should see the Security Warning near the top of the screen. Then enable this content.

**Step 1: Add your Proposal Name in Cell A2.** Afterwards, it will automatically appear in all three worksheet tabs in your workbook. Save your analysis with a unique name and date in the file name, retain the Microsoft Excel .xlsm file extension as this retains the macros embedded in the file. Remember this analysis is intended to be for Forest Service fire program management costs (which mean it includes all NFS treatment costs implemented to change fire behavior, and is to include your entire proposal area. If you are planning to compare federal versus all lands, multiple treatment options, fuel treatments only compared to all vegetation treatments, NFS treatments only compared to all lands treatments, etc., save each file accordingly. You may wish to use the move / copy command to create a copy after completing some of the information so you can make comparisons, if so, be sure to name each tab so when printed the files are distinguishable. And realize that the R-CAT Results Summary tab is only set up to summarize the results from Table 1. Wildfire Cost Analysis.

**Step 2: Enter information needed to customize your calculation table.** First enter applicable Start and End Calendar Years in Cells A4, and A5 using pull down menus. Start year will be 2010 for the first ten proposals selected, and the first year of implementation with CFLRP funding for all other proposals. Current legislation only authorizes CFLR Fund until 2019, so this will be the most common end year. However, some proposals may plan implementation for less than the full authorization period. If the pull downs do not work, see the section above "Enabling Macros"

**Step 3: Next, use the pull down menu in cell A11 to select the average number of years treatments are effective, including the implementation year.** The duration of treatment effectiveness of unmaintained treatments varies between cover types. In some it may be as little as three years, in others it may be as long as 30 years. You may need to do some thinking about these estimates if you are planning treatments in different cover types which have a wide range of effectiveness duration. For example, if you have some chaparral treatments and some mixed conifer treatments in your project area, you may need to do some additional weighting to represent cumulative effectiveness. If you have a reason to specify different durations over the span of the proposal, contact someone who can carefully help you customize you workbook to ensure calculations remain technically correct if you make adjustment here, call an economist for assistance if needed, and DOCUMENT what you have changed.

Now that your table has been customized to the duration of your treatment implementation and set to calculate savings based on growing and then waning cumulative treatment effectiveness,

**Enter Your Total Treatment Acres in Cell A9**. If you are doing a prospective or planning analysis you should enter these according to your expectations of what can be accomplished by the end year. Note that the analysis runs by crediting each year with a portion of the savings achievable at the last year of your treatment implementation. So this number of acres has a strong influence on your results. You should eventually implement 100% of your treatment acres in cell A9, in order for FSim/SCI analysis to work properly. **Next manually enter your treatment acres by year for each year in row 6, ending in the same year you selected in cell A5.** To check that these numbers match, sum all acres in row 6 from start year to end year, it should equal what you entered in cell A9.

If you are doing a retrospective analysis you should enter your actual treatment acres from annual reports. Caution, if your implementation was much less or more than you modeled with FSim and SCI, you should consider reproducing your FSim/SCI outputs to get accurate modeling results.

**Step 4: Enter average revenue per treatment acre (row 14) from recent transaction evidence or residual value appraisals and enter average agency costs per treatment acre by year for each year in row 15, ending in the same year you selected in cell A5.** If you are planning treatments, use the best estimates you can produce for treatments. These will be an average of treatment revenues in row 14 and average cost per year in row 15, or you can change these averages over time due to the places and types of treatments. Net revenues may change slightly if you expect new markets such as biomass revenue. For a prospective analysis, these costs should include the portion of planning costs attributable to fuel treatments, sale prep and sale admin costs per acre. Document what you have entered on the documentation page.

For a retrospective analysis, if you have actual per acre revenues and expenditures from your annual monitoring, enter these amounts per year directly into row 14 and 15 for each year. Document what you have entered on the documentation page.

*WARNING: Methodological deviations from the recommended protocol for all subsequent steps will raise question about the credibility of the analysis and will require substantial documentation to justify results. The outputs from this spreadsheet are only as good as the inputs. Documentation need include other models used, data sources used, estimates made, along with associated justifications and should be agreed upon by all relevant experts, use the R-CAT Documentation Tab.*

**Step 5: Enter the pretreatment median or average annual Forest Service <u>large</u> fire season suppression costs for your entire proposal landscape in cell A32**. Ideally here you will enter median expected fire season cost per year pre treatment from FSim / SCI Analyst in Cell A32. SCI is the Stratified Cost Index, a regression based model found in WFDSS estimates the costs of large fires based on historical data. There are two NFS models, with a parameter for each region, as well as four USDI models. These results should come from someone trained in how to analyze FSim outputs with SCI. Because SCI does not include BAER, rehabilitation, nor reforestation costs there are options to include this information as well. Alternatively, you can use historic records to estimate this acreage. Please document the name of your analyst in the R-CAT Documentation Page.

**Step 6: Enter median <u>large</u> fire season acres for your pre-treatment landscape from Fire Analyst in Cell A34.** Ideally, these results come from someone trained in how to analyze FSim outputs with SCI. Alternatively, you can use historic records to estimate this acreage.

**Step 7: Enter the post treatment median or average annual Forest Service <u>large</u> fire season suppression costs for your entire proposal landscape in cell A36.** Ideally, here you will enter median expected fire season cost per year pre treatment from FSim / SCI Analyst in Cell A36. Alternatively, you can use historic cost records with justified adjustments expected based on a fully implemented proposal to estimate this acreage.

Note there is a cell in the worksheet designed to provide the user feedback about the percent of the pretreatment costs this figure represents. If you see this is greater than 100 percent you immediately know that the modeling suggests your proposed treatment schedule will lead to additional large fire costs.

**Step 8: Enter median <u>large</u> fire season acres for your post-treatment landscape from fire analyst in Cell A39.** Ideally, these results also come from someone trained in how to analyze FSim outputs with SCI. Alternatively, you can use historic records with justified adjustments expected based on a fully implemented proposal to estimate this acreage.

Note there is a cell in the worksheet designed to provide the user feedback about the percent of the pretreatment costs this figure represents. If you see this is greater than 100 percent you immediately know that the modeling suggests your proposed treatment schedule will lead to additional acres burned with large fires.

*Congratulations, you have completed the <u>basic</u> fire program cost savings analysis. If you click on the four macro buttons in Column E from E31 to E40, the results of your work will be displayed in the R-CAT Results Summary Page. The remaining steps are optional and allow you to enter additional cost savings avenues, including small fires, post fire costs and cost savings from substitution of beneficial use fires for full suppression in the future.* ***Save your file!!!***

**Optional Step 9: Adjust the annual BAER / Rehabilitation / Reforestation pre-treatment costs (B33) and post-treatment (B37) based on best approximation if needed.** Nationally, BAER spending is roughly 3 percent of total suppression costs. The default setting for annual pre treatment and post treatment costs are $0. If you feel there would be decreases in these the costs following implementation of your treatments you can adjust these figures. Just be sure to document your justification.

**Optional Step 10: Enter annual small fire costs pretreatment (cell C32) and post treatment (cell C36) based on P code data and best approximation if needed.** Your small fire costs estimate should be reflective of the small fire costs in your project area. If possible, estimate your annual small fire costs through a GIS analysis of what percent of Class A-D fires occurred in your project area compared to the source of these estimates.

| NWCG's standard data values | Description |
|---|---|
| **A** | **Greater than 0 but less than or equal to 0.25 Acres** |
| **B** | **0.26 to 9.9 Acres** |
| **C** | **10.0 to 99.9 Acres** |
| **D** | **100 to 299 Acres** |
| E | 300 to 999 Acres |
| F | 1000 to 4999 Acres |
| G | 5000+ Acres |

For example, if you have portions of two districts, try to determine what portion of the pre-suppression and initial attack costs are attributable to this area compared to each of the hosting national forests. This figure should be the same for pre and post treatment unless you intentionally adjust it to reflect reductions in post-fire costs as a result of your treatments. If you do adjust provide justification in the R-CAT Documentation tab.

**Optional Step 11: Adjustment for increased use of beneficial use fires / decreased use of full suppression.** One expectation of CFLRP is that treatments will allow fire managers more options to select a monitoring strategy on portions of some large fires and some entire fires following treatment. If you are interested in making this adjustment, you should consider what portion of your project area is suitable for this firefighting strategy post-treatment. We suggest you may want to use a GIS exercise with your current Fire Management Plan to estimate the potential CONTIGUOUS percent area of your proposal landscape where full suppression could be replaced with low-cost monitoring of fire for beneficial use. Carefully document this calculation. Provide high (D34), moderate (D36) and low (D38) estimates of the percent of your proposal area where this transition in fire management strategy is expected. Next enter the average for the percentage of beneficial use large fire costs compared to full suppression costs (cell D40), using historic P and G code information for your proposal area if available. These entries should all be substantiated through solid documentation. Justify your estimates and logic in the appropriate cells for this topic on the documentation page.

*Congratulations, you have completed the full fire program cost savings analysis. If you click on the four macro buttons in Column E from E31 to E40, the results of your work will be displayed in the R-CAT Results Summary Page.* ***Save your file as a macro-enabled Excel file (xxxx.xlsm)!!!***

# Appendix Z: Demonstration of the work required by FSim/SCI modeler to support your project, to be used in combination with the Deschutes demonstration.

**R-CAT Fire Cost Analysis: Pairing FSim with SCI to Quantify the Effectiveness of Fuel Treatments at Reducing Wildfire Suppression Costs**

**Illustration on the Deschutes National Forest**

**Introduction**

This document demonstrates methodologies that can be used to estimate cost savings from fuel treatments in terms of reduced wildfire suppression costs. The demonstration is intended to support analysts planning fuel treatments under the Collaborative Forest Landscape Restoration (CFLR) Program, which aims to (among other goals) facilitate reductions in wildfire management costs. Our approach pairs wildfire simulation outputs with a regression cost model, estimating the influence of fuel treatments on distributions of wildfire size and suppression cost. The method is based on emerging applications of wildfire risk science to inform decision making. It is important to note the methodologies developed here only account for cost savings due to reduced fire sizes, not changes in fire intensity.

**Key Models Used:**

Fire Modeling: FSim
Fire Cost: Stratified Cost Index (SCI)

**Methods**

*General: Suppression Cost Estimation Process for Fuel Treatment Evaluation (see Figure 1)*

1. Design and spatially layout prospective fuel treatments. Modify input data for FSim appropriately given the nature of the treatment.
2. Generate FSim wildfire simulation model outputs with and without fuel treatments. The treatment difference is reflected in final fire size; all other variables are constant for a given fire. Note some fires may actually grow larger after fuel treatments.
3. LANDFIRE database query - Given the lat/long of the ignition point the query outputs relevant geospatial data such as slope, aspect, elevation, fuel model, distance to town, etc. (See Table 1) Access to this database is currently limited. The current recommended protocol is to contact Matt Thompson (RMRS) and provide him with output from FSim. If the same set of fires are always used (as is recommended), this need only be a one-time step in which Matt will go through the appropriate measures to obtain LANDFIRE output for each simulated fire. Users can later experiment with alternative fuel treatment regimes to see subsequent changes to fire size.
4. Variables output from FSim and LANDFIRE are aggregated and fed into the SCI regression cost model to estimate the expected suppression cost for each fire (See Table 2).
5. Compare per fire expected suppression costs with and without fuel treatments. Differences in costs reflect expected savings (or increased cost) due to treatment.

6. Compare annual expected fire suppression costs. To annualize costs, first a simulation year must be assigned to every fire. In order to assign an appropriate simulation year users must identify every unique “Proc” and “Sim_Yr” combination.

**Table 1:** Variables used in SCI regression model [dependent variable = ln(wildland fire suppression expenditures/acre)].

| Fire characteristics | Variable definition | Source |
|---|---|---|
| Size | | |
| Ln(Total acres burned) | Natural log of total acres within the wildfire perimeter | FSim |
| Fire environment | | |
| Aspect | Sine and cosine of aspect at point of origin in 45° increments | LANDFIRE |
| Slope | Slope percent at point of origin | LANDFIRE |
| Elevation | Elevation at point of origin | LANDFIRE |
| Fuel Type | Dummy variables representing fuel type at point of origin.; Brush = NFDRS fuel models F and Q; Brush4 = NFDRS fuel models B and O; Slash = NFDRS fuel models J, K, and I; Timber = NFDRS fuel models H, R, E, P, U, and G; Grass (reference category) = NFDRS fuel models A, L, S, C, T, and N | LANDFIRE |
| ERC | ERC calculated from ignition point using nearest weather station information (cumulative frequency) | FSim |
| Values at risk | | |
| ln(Distance to nearest town) | Natural log of distance from ignition to nearest census designated place | LANDFIRE |
| ln(Total housing value 20) | Natural log of total housing value in 20-mi radius from point of origin (census data)/100,000 | LANDFIRE |
| Wilderness area | Dummy variables indicating whether fire was in a wilderness area | LANDFIRE |
| ln(Distance to wilderness boundary) | If in a wilderness area, natural log of distance to area boundary | LANDFIRE |
| Region | Dummy variables for National Forest System region (reference category for western model = region 1) | FSim |

**Table 2:** Ordinary least squares regression model for SCI. Model updated from (Gebert et al. 2007) and provided by Krista Gebert (Regional Economist, Northern Region (R1), US Forest Service, 2009).

| **Variable** | **Coefficient** | |
|---|---|---|
| | **R1-R6** | **R8-R9** |
| Ln(Total acres burned) | -0.3207 | 0.2594 |
| Fire environment | | |
| Aspect (cosine) | -0.1431 | - |
| Aspect (sine) | -0.0509 | - |
| Slope | 0.1134 | 0.2441 |
| Elevation | 0.3603 | - |
| Brush | -0.0023 | - |
| Brush4 | 0.5128 | 1.2698 |
| Timber | 0.8553 | 0.7735 |
| Slash | 0.5673 | - |
| Fuel Model D | - | 0.8942 |
| ERC | 0.0195 | 0.0168 |
| Values at risk | | |
| ln(Distance to nearest town) | -0.2623 | - |
| ln(Total housing value 20) | 0.1422 | 0.1366 |
| Wilderness area | 0.3922 | - |
| ln(Distance to wilderness boundary) | -0.5856 | - |
| Region | | |
| Region 2 | -0.3518 | - |
| Region 3 | 0.0261 | - |
| Region 4 | 0.1394 | - |
| Region 5 | 1.3933 | - |
| Region 6 | 1.2028 | - |
| Region 8 | - | 0.7917 |
| Constant | 1.9823 | -1.5585 |

*Specific: DNF Case Study*

- Identical ignitions and weather conditions simulated under different landscape conditions resulting from fuel treatment. Fire size is key variable that changes. Some fires grow bigger, most decrease in size. Many fires on treated landscape don't grow to 300 acres; considered caught successfully in initial attack. So, treated landscape a) means more fires are caught in IA, b) shifts fire size distribution to left, c) shifts fire cost distribution to the left, and d) shifts per acre costs to the right (because per acre costs generally smaller for larger fires…)
- Suppression costs for each fire (ignition) estimated at both sizes (untreated and treated landscape)
- Filters applied to fires to weed out:
  - o < 300 acre fires not assigned costs with SCI model; considered IA
  - o > 100,000 acre fires removed from sample (FSim produces some very large fire sizes; removal is not so much a statement that such extremely large fires couldn't happen but rather that it is inappropriate to cost them with SCI model; in general it is inappropriate to use models to predict well outside the sample)

- 100,000 acre limit justified on basis of B&B complex fire reaching ~91,000 acres
- Historic fire size distributions could also be used to inform definition of upper threshold
- Another approach is to assign an average cost for all fires above a certain size threshold; this would effectively move size and cost distributions to right but might not be more informative in terms of relative risk pre- and post-treatment

**Fuel Treatments**

The prospective fuel treatment alternative considered here is deemed a "Max Treat" alternative thought to represent the upper limit of feasible fuel treatments on the Deschutes. Filters were applied to exclude treatments from reserved locations (endangered habitat, etc.) limiting available treatment areas to: general forest matrix, deer habitat, visual corridors, and LSRs when none of the area is or potentially could be NSO habitat. A second filter identified stands eligible for treatment based on PVG-specific basal area thresholds. Fuel treatments are modeled as a 3-year sequence: thin from below (year 1), site removal of surface fuels (year 2), and under burning (year 3).

In total 323,883 acres were treated, out of 1,612,466,542 acres under Deschutes ownership. Figure 2 identifies the locations of these simulated treatments (treatments highlighted in grey). This treatment regime corresponds to treating approximately 20% of the landscape (but without explicit spatial treatment of fuel treatments to protect specific resources or to prevent spread; see Ager et al. 2010 for a discussion of influence of treatment location).

**Results**

Total # of simulated fires (before applying filters): 515,474
Total # of simulated fire seasons (all unique combinations of processor # and simulation year): 92,619

Filter #1: Only include ignition locations within Deschutes National Forest boundaries (a more representative set of fires could be modeled by using a buffer including some fires that ignited near to the forest boundary.)
Total Fires after Filter 1 = 210,110

Filter #2: Fire Size < 300 Ac (considered caught in IA; SCI model doesn't cost fires < 300 ac)
Filter #3: Fire Size > 100,000 Ac (due to limitations of predicting far out of sample with SCI)

Total # NT fires after applying Filters 2 & 3: 163,250
Total # MT fires after applying Filters 2 & 3: 149,200

**Table 1:** Summary Statistics on fire size distributions. NT = No Treatments; MT = Max Treat. Total of n = 210,110 fires are included in these results; broken up by filter type (Filters 2-3 remove fires from the costing analysis).

| **Results / Scenario** | | **NT** | **MT** |
|---|---|---|---|
| Small Fires (< 300 Ac) - EXCLUDED | | **n = 39,499** | **n = 57,685** |
| | Min | 72 | 72 |
| | Max | 288 | 288 |
| | Mean | 145 | 132 |
| | Median | 126 | 108 |
| | Standard Deviation | 69 | 28 |
| Very Large Fires (>100,000 Ac) - EXCLUDED | | **n = 7,361** | **n = 3,225** |
| | Min | 100,014 | 100,050 |
| | Max | 1,401,956 | 881,784 |
| | Mean | 184,610 | 172,669 |
| | Median | 148,705 | 142,383 |
| | Standard Deviation | 105,169 | 88,160 |
| Large Fires – INCLUDED | | **n = 163,250** | **n = 149,200** |
| | Min | 306 | 306 |
| | Max | 99,978 | 99,978 |
| | Mean | 12,426 | 9,670 |
| | Median | 4,161 | 2,990 |
| | Standard Deviation | 18,722 | 15,899 |

Table 1 illustrates the number of fires that were removed from further analysis by our filtering process. It further illustrates that after treatment average fire size decreases to 78%, and median fire size to 72% of pre-treatment sizes.

**Table 2:** Per fire costs for those large fires that were assigned costs using the SCI model (See Table 1).

| **Results / Scenario** | | **NT (n = 163,250)** | **MT (n = 149,200)** |
|---|---|---|---|
| Cost ($) | | | |
| | Min | 132,638 | 144,796 |
| | Max | 147,746,578 | 132,104,860 |
| | Mean | 7,722,142 | 6,685,129 |
| | Median | 3,889,723 | 3,197,661 |
| | Standard Deviation | 10,387,607 | 9,503,682 |

Table 2 illustrates that per fire mean cost decreases to 87% and median cost decreases to 82% of pre-treatment costs.

**Table 3:** Annualized Results for large fires that were assigned costs. Total of n = 77,190 fire seasons were modeled.

| **Results / Scenario** | | **NT** | **MT** |
|---|---|---|---|
| Size (Ac) | | | |
| | Min | 0 | 0 |
| | Max | 418,357 | 388,255 |
| | Mean | 26,280 | 18,692 |
| | Median | 10,268 | 6,054 |
| | Standard Deviation | 37,286 | 29,838 |
| Cost ($) | | | |
| | Min | 0 | 0 |
| | Max | 257,266,174 | 239,770,407 |
| | Mean | 16,331,646 | 12,921,638 |
| | Median | 8,342,665 | 5,868,448 |
| | Standard Deviation | 21,548,446 | 18,562,098 |

0 means either there were no large fires in that season, which could mean 0 ignitions, or if ignitions did occur they were all either caught in IA (Filter 2), too large to be modeled with SCI (Filter 3), or some combination thereof.

Per season average fire size decreased to 71% of pre-treatment, median fire size to 59% of pre-treatment levels. Per season mean large fire suppression costs decreased to 79%, and median costs to 70% of pre-treatment levels.

Figures 3-8 illustrate FSim results for burn probability (BP) and conditional flame length (CFL) for the ‘no treat’ and ‘max treat’ landscapes. Figures 5 and 8 represent the differences between the maps. In Figure 5, positive values for the difference indicate burn probabilities decreased due to fuel treatments, indicated on a red through green scale. Blue values represent burn probabilities actually increased under the treatment scenario. Two things to note: 1) magnitude of largest increase (0.00013) less than an order of magnitude smaller than magnitude of largest decrease (0.004), and 2) this behavior not altogether unexpected due to phenomenon of decreased tree density facilitating quicker winds speeds and subsequent fire growth.

Figures 9-12 display boxplots comparing the ‘no treat’ and ‘max treat’ landscapes across burn probability, conditional flame length, annualized large fire size distribution, and annualized large fire cost distribution.

This information on fire intensity can be paired with maps of valued resources and fire management plans to indicate where damages to resources are likely to decrease, and to indicate where beneficial fire use due to natural ignitions may be allowed to increase (thereby possibly reducing expected suppression costs beyond what is modeled with the SCI process.)

**Limitations/considerations of FSim model**

- Users need to define spatial filter to define set of fires to include in modeling exercise
- Post-processing to exclude fires whose size may exceed range of data used to build SCI model
- Need to post-process Proc & Sim_Yr attributes to aggregate into unique fire seasons
- Data preparation with ArcFuels necessary
- Learning curve for general expertise with FSim

**Limitations/considerations of SCI model**

- Data requirements, need to outsource some data acquisition (LANDFIRE query), need for users experienced with management of large datasets, ability to write macros definitely a plus
- Large variability in fire costs
- Cost estimates are non-spatial
- Based on ignition point and start time
- Limited resource valuation
- Complexes are difficult to deal with
- Not good for multi-jurisdictional incidents with a lot of state involvement

**Limitations of FSim + SCI modeling exercise**

- Only accounts for differences in expected suppression cost due to changes in fire size distributions
- Uncertainty surrounding both FSim & SCI

**Figure 1:** Flowchart for the processes involved in estimating suppression expenditures for simulated fires.

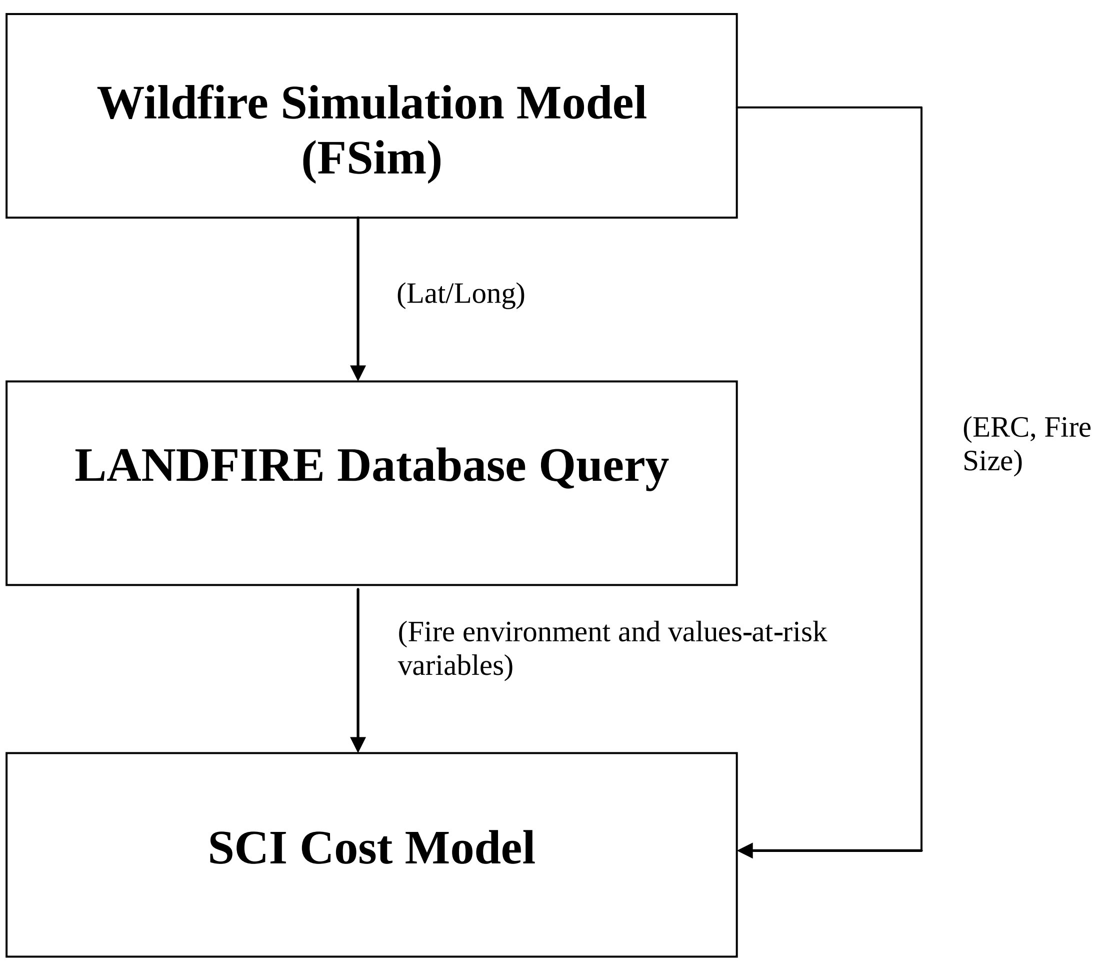


**Figure 2:** Locations of simulated fuel treatment polygons within Deschutes National Forest boundary.

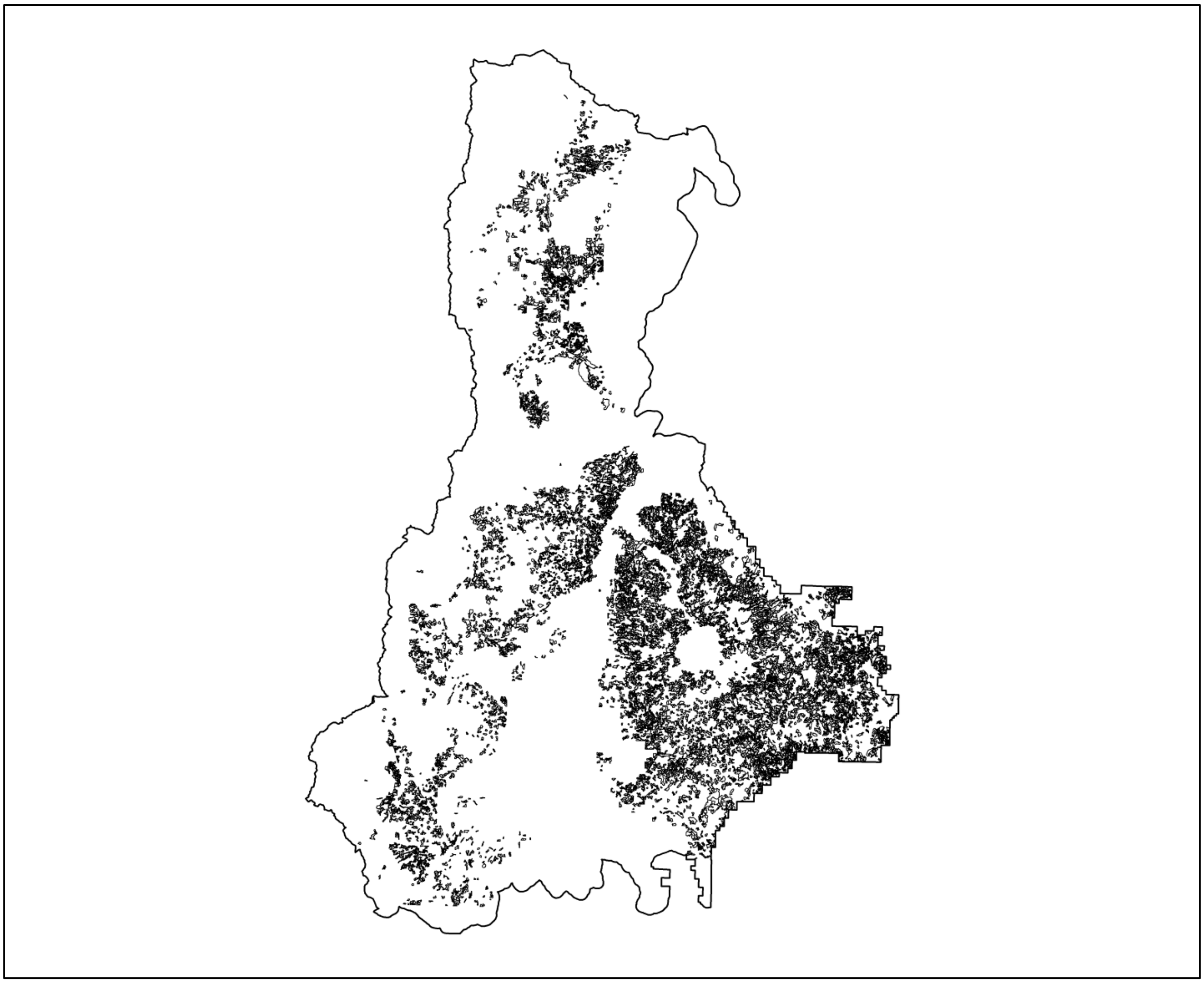


**Figure 3:** Burn probability for the "no treat" modeled landscape.

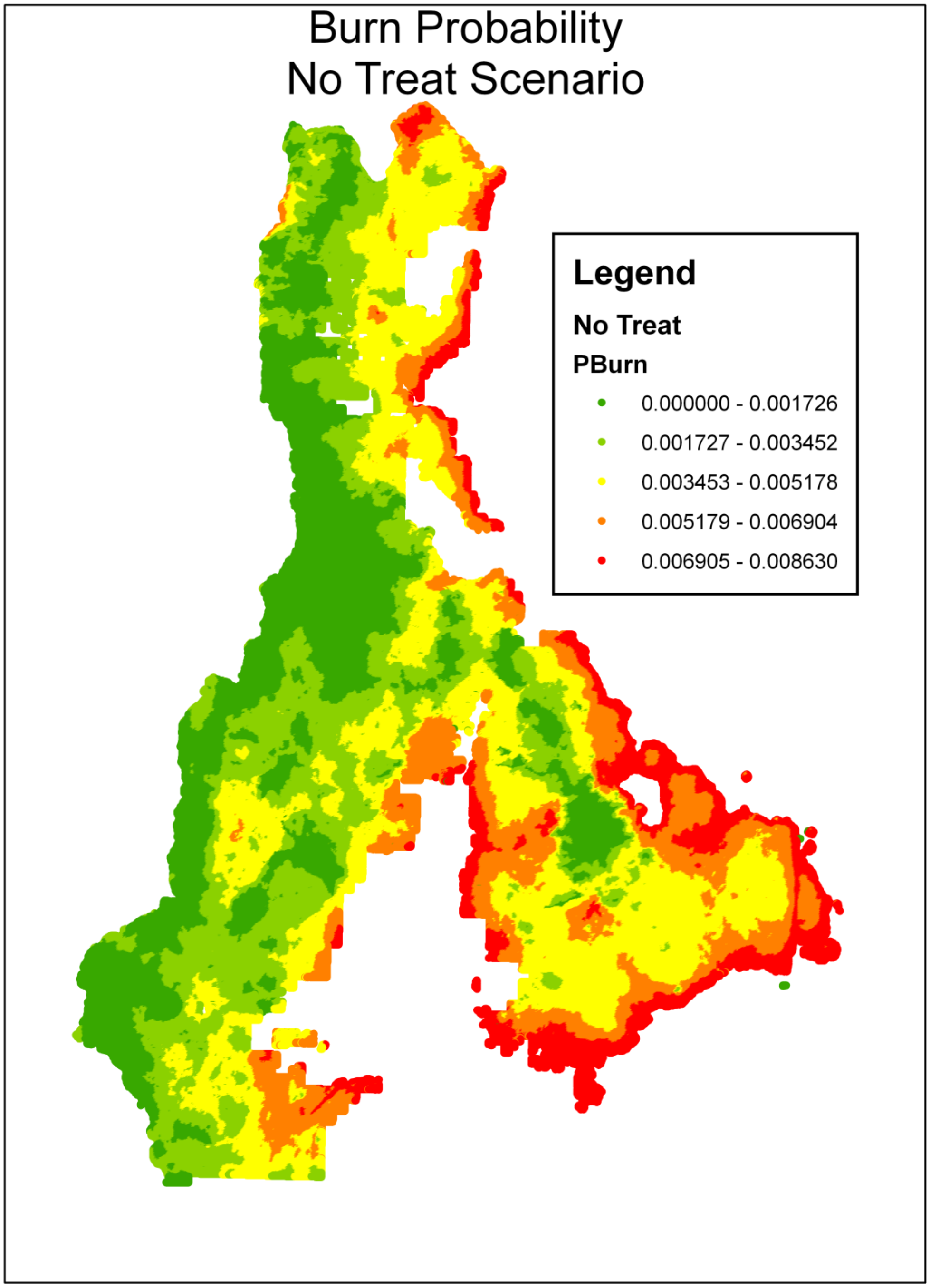


**Figure 4:** Burn probability for the "max treat" modeled landscape.

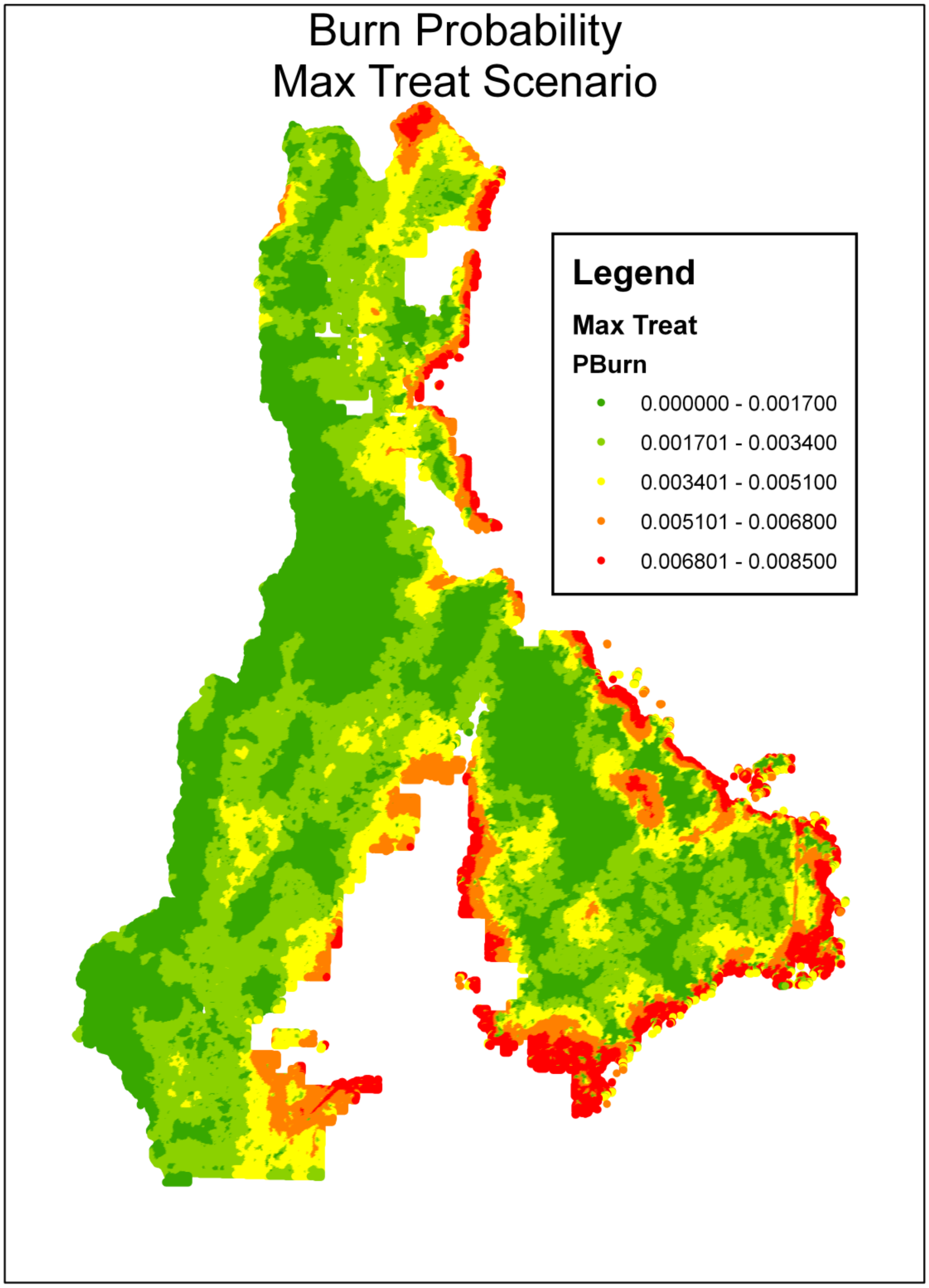


**Figure 5:** Burn probability difference between the "no treat" and "max treat" modeled landscapes.

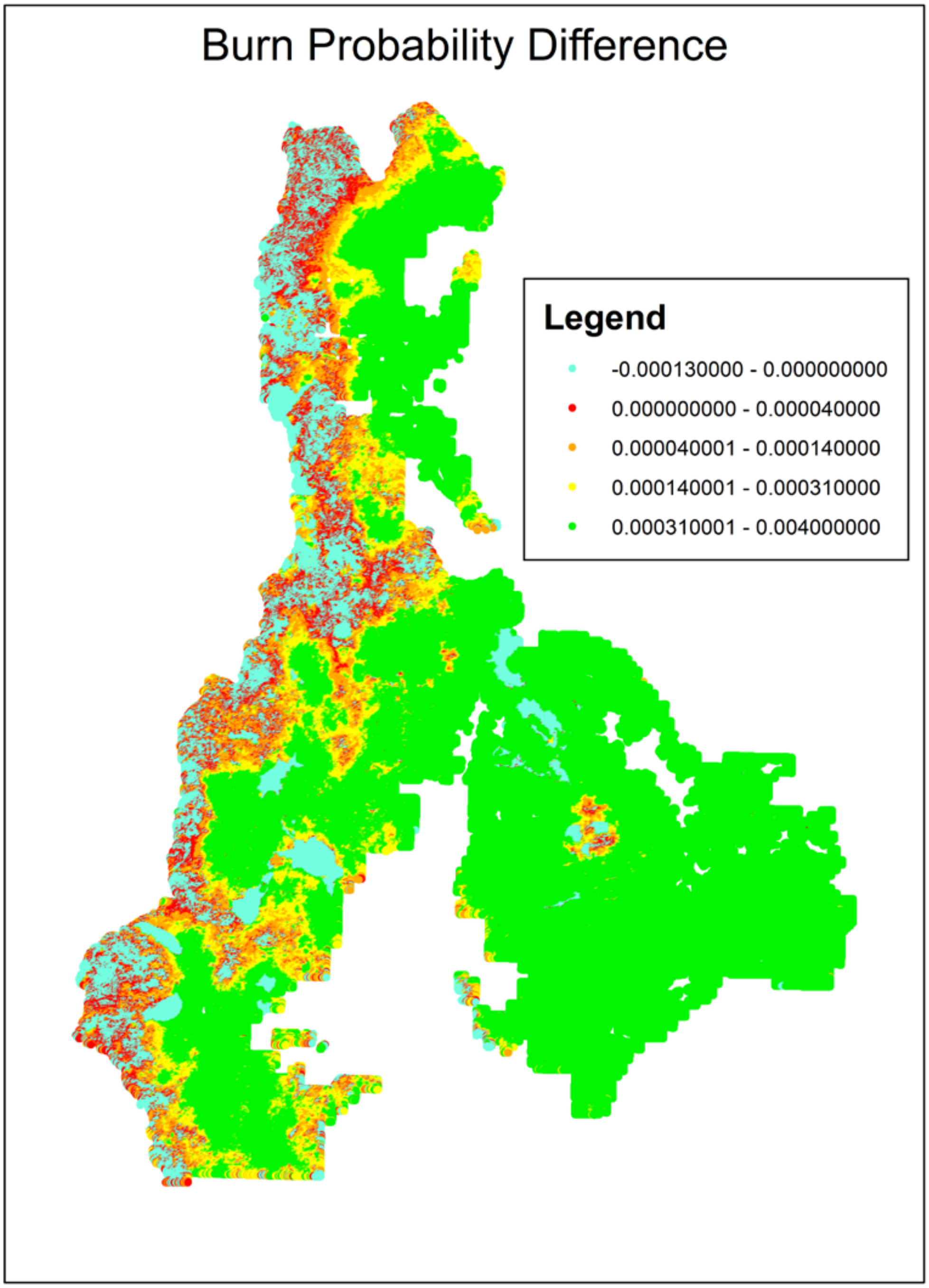


**Figure 6:** Conditional flame length, by flame length category, for the "no treat" modeled landscape.

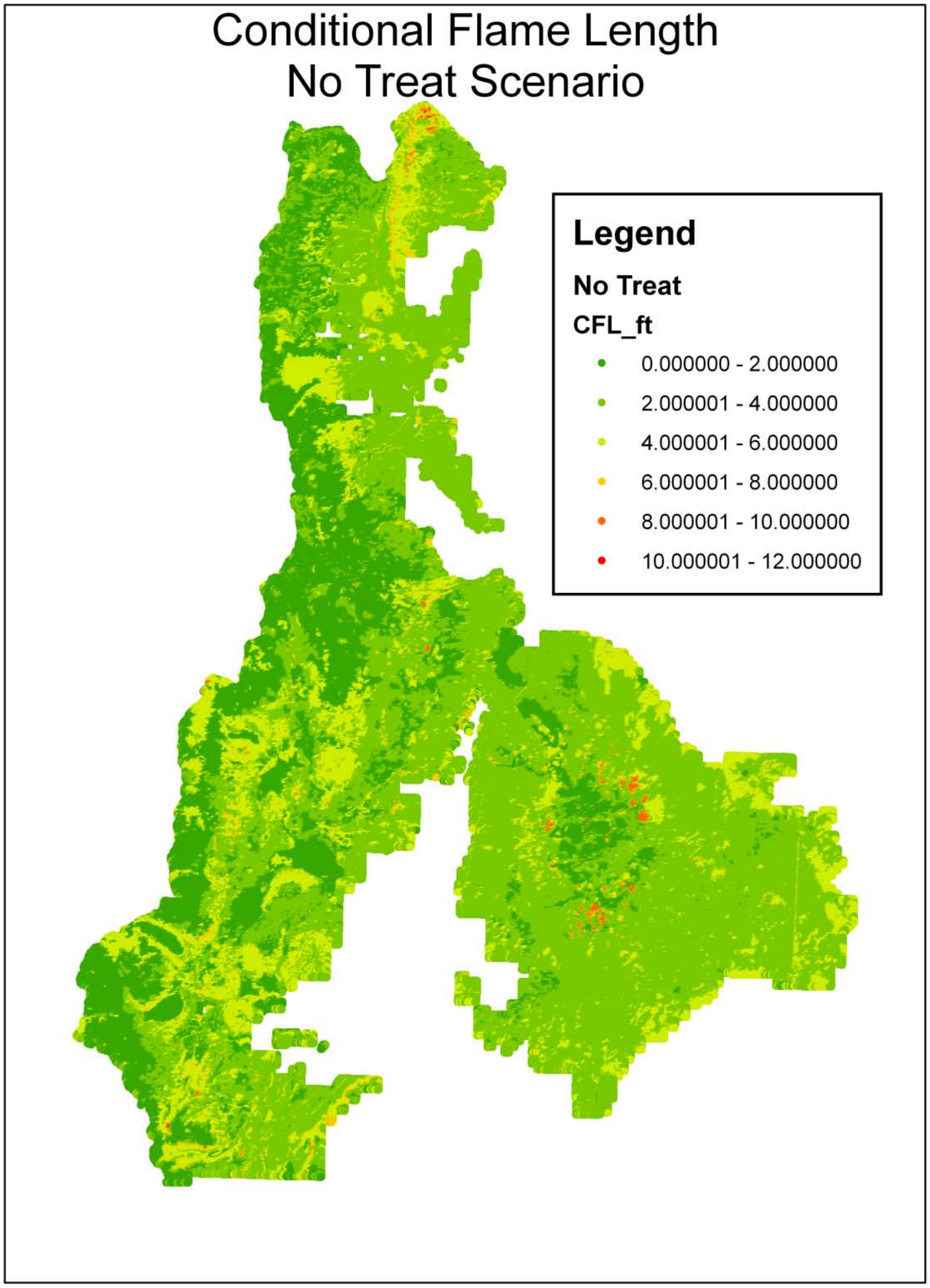


**Figure 7:** Conditional flame length, by flame length category, for the "max treat" modeled landscape.

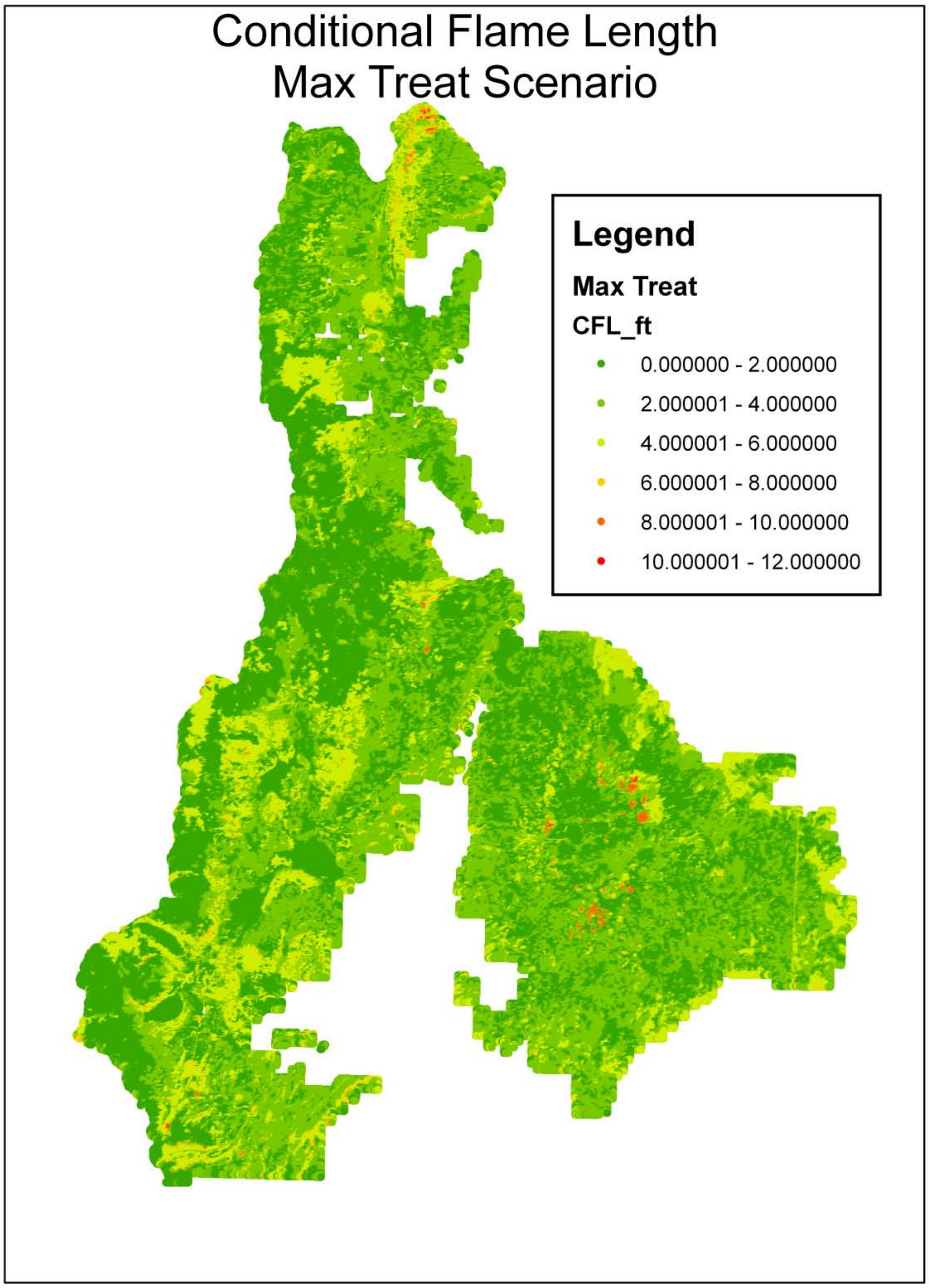


**Figure 8:** Difference in conditional flame length between the “no treat” and “max treat” modeled landscapes.

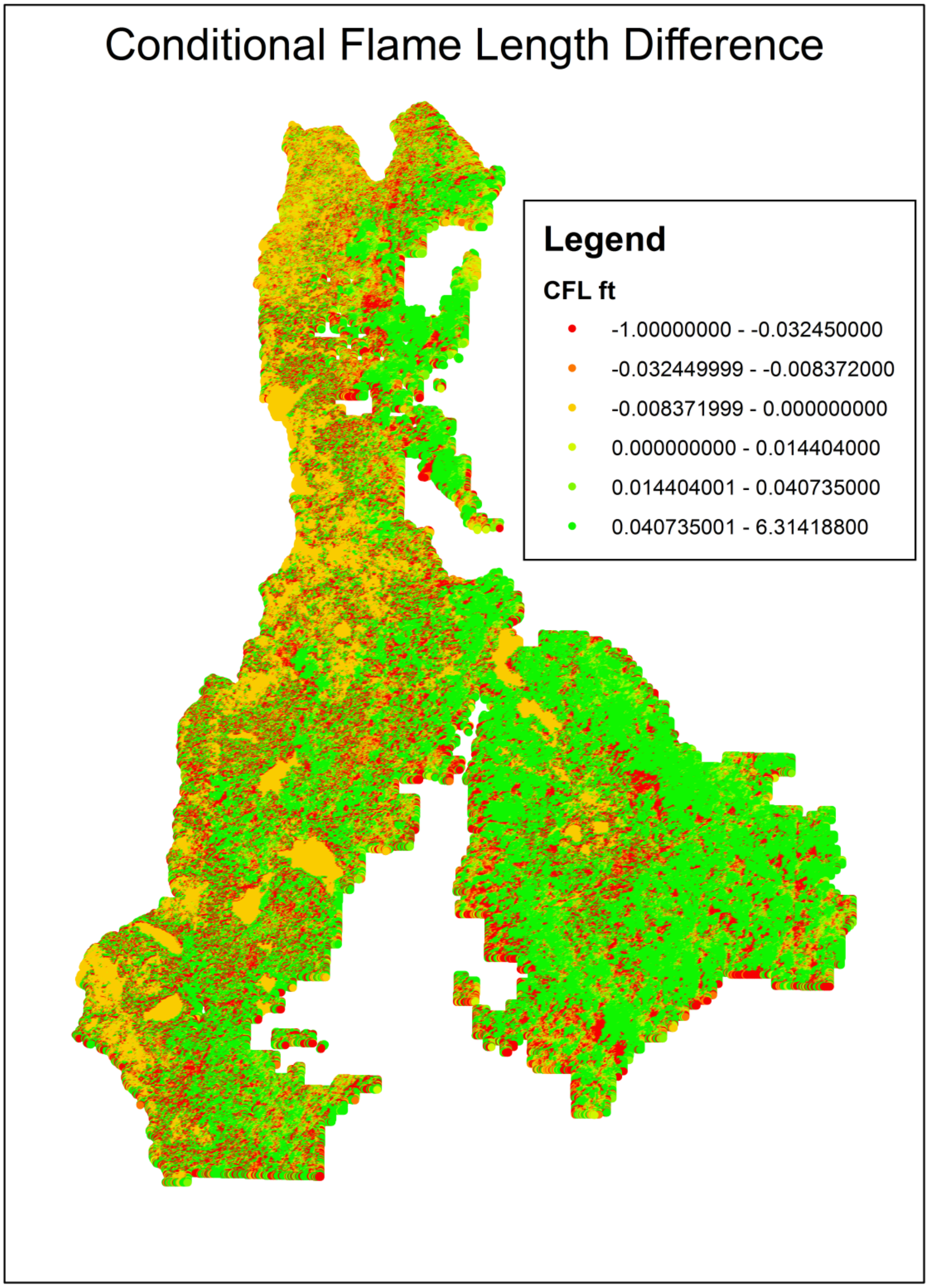


**Figure 9:** Boxplot for burn probability across 'no treat' and 'max treat' landscapes.

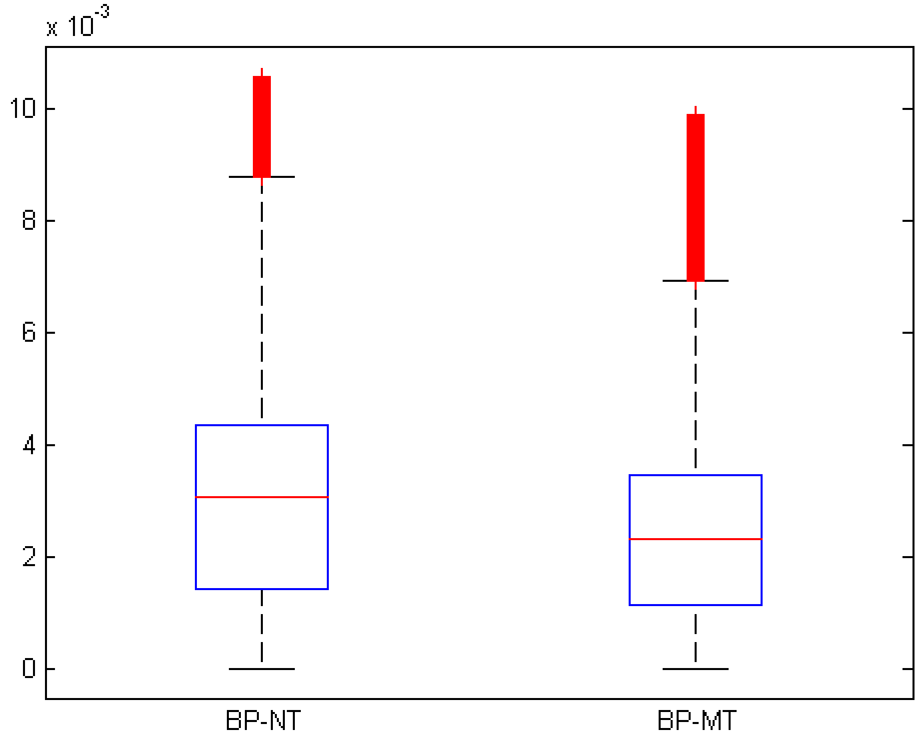


**Figure 10** Boxplot for conditional flame length across treated landscapes.

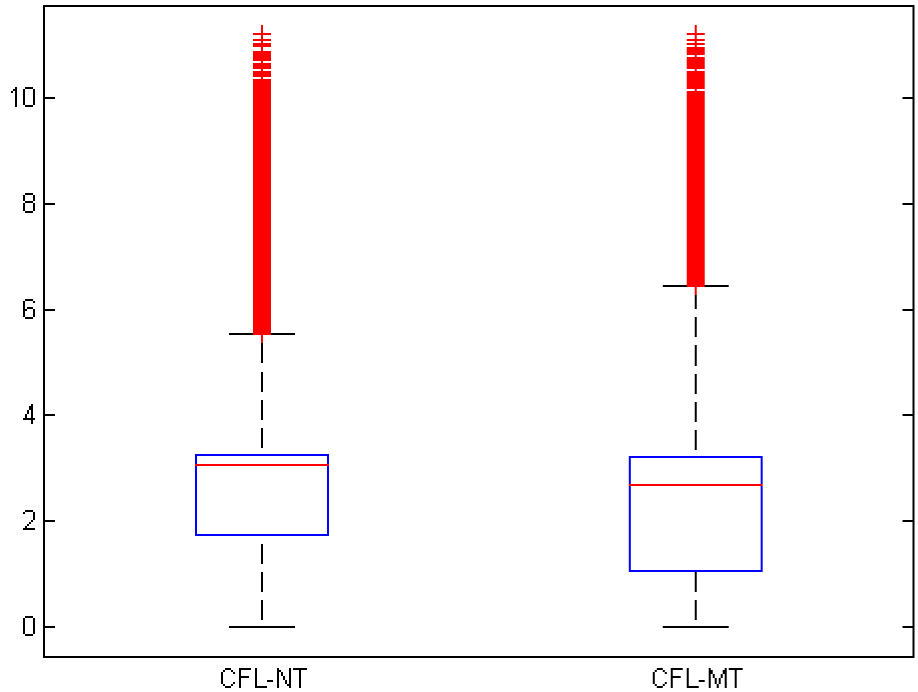


**Figure 11:** Boxplot for annualized fire size distributions.

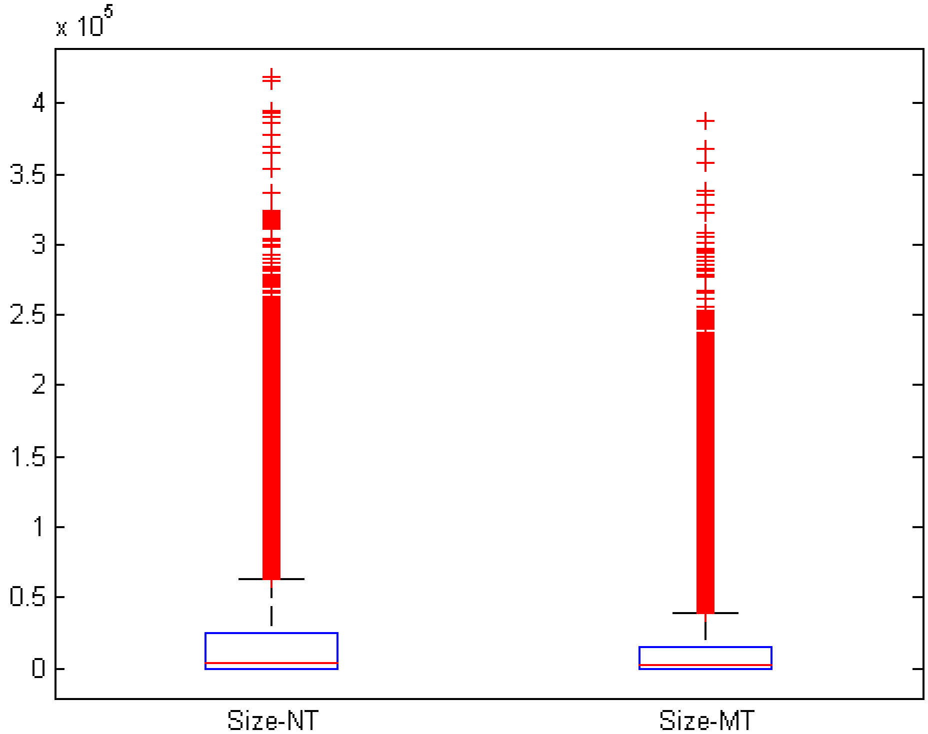
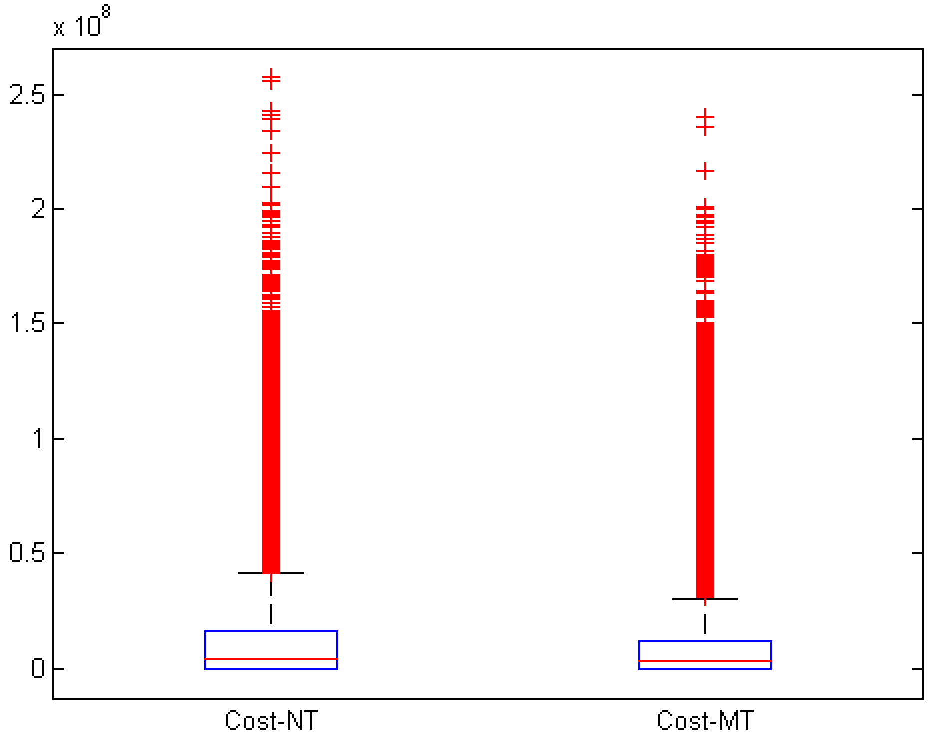


**Figure 12:** Boxplot for annual fire cost distributions.




Note: 1) Unfortunately, the outlier symbols in Figures 11 and 12 are so dense that you can't tell what is going on in that region, and 2) the outliers "squash" the rest of the boxplot down so much that it diminishes ability to see any differences. One remedy would be to plot without the outliers and state that they are excluded. Alternatively, you could include them in a separate inset or plot maybe.