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Optimizing the Location of Fuel Treatments Over Time at Landscape Scales

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Fuel treatments are a necessity, but planning for and conducting these treatments within a variety of operational and budgetary constraints is not always easy. Credit: U.S. Forest Service.

Optimizing the Location of Fuel Treatments Over Time at Landscape Scales

Summary

Fuel treatments are a vital part of forest management—but when faced with limited budgets, narrow burning windows, and air quality restrictions, it can be challenging to prioritize where, when, and how fuel treatments should be applied across the landscape to achieve the most benefit. To help ease this process, land managers can turn to various standalone models, capabilities, and decision support systems. While these tools address various aspects of fuel treatments, there is no one integrated solution that can provide the combined functionality needed to handle the strategic scheduling of fuel treatments, the spatial and temporal changes of fuel treatment effects on a landscape, and the budgetary and operational constraints related to maintenance of treatments. Therefore, the goal of this project was to develop an integrated solution that could fulfill these needs. The solution, now known as OptFuels, incorporates land management optimization functionality (MAGIS), vegetation simulation capabilities (Forest Vegetation Simulator and the Fire and Fuels Extension [FVS-FFE]), and fire behavior modeling functionality (FlamMap). By integrating these proven technologies, project investigators and developers hoped to provide land managers with a more streamlined ability to plan, schedule, and apply the most cost-effective and landscape-appropriate fuel treatments available.

Key Findings

- Testing results confirmed that OptFuels can substantially reduce the expected loss of values at risk across a landscape by scheduling fuel treatments across multiple planning periods.
- Researchers discovered that the inventory data needed to produce Forest Vegetation Simulation (FVS)-ready tree list and stand data were unavailable for stand polygons in forested landscapes at the time of the study.

The need for integration

There is no single model that incorporates the combined functionality forest managers need to strategically schedule fuel treatments while considering spatial and temporal fuel treatment effects on a landscape and fuel treatment maintenance under various budgetary and operational constraints.

That all changed when researchers and software developers collaborated on a recent project. The goal of that project was to integrate existing land management, vegetation simulation, and fire behavior modeling tools into one solution using components of MAGIS, FVS-FFE, FlamMap, and a newly developed optimizer for scheduling fuel treatments. The solution would allow for automated data transfer between the different models, thus providing an easier way to use multiple models to analyze alternative fuel management schedules. Once complete, the solution would then be validated on two landscapes.

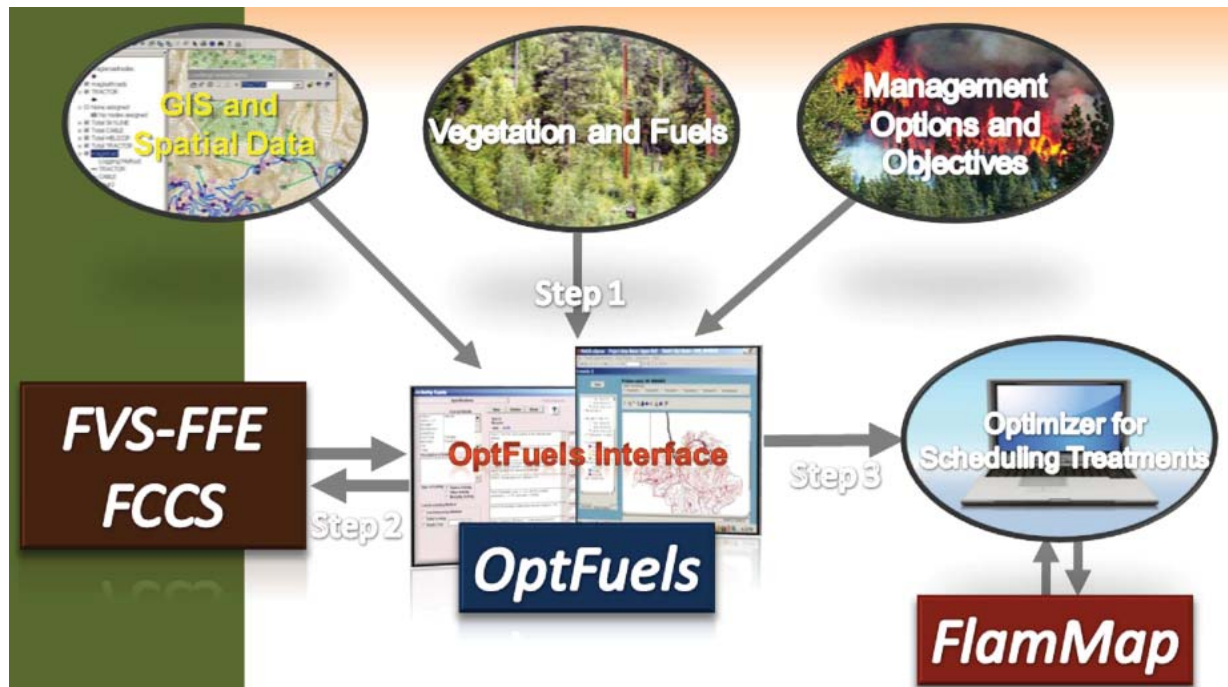
The OptFuels solution

As a result of this project, that integrated solution—now known as OptFuels—was born. Principal investigator Greg Jones stated, “The vision underlying OptFuels was to

develop a system for scheduling fuel treatments and re-treatments both spatially and temporally on a landscape to minimize undesired fire [effects] over time for given levels of budget per time period, while satisfying other resource objectives and operability constraints.”

The OptFuels system includes:

- **Components of MAGIS**—A land management optimization tool for spatially scheduling treatments that effectively meet resource and management objectives while satisfying user-defined resource and operational constraints.
- **FVS-FFE**—A vegetation simulation tool that can project vegetation change over planning periods, predict the resulting fuel parameters for fire behavior modeling, and evaluate proposed fuel treatment effectiveness in terms of potential fire effects on short- and long-term stand dynamics. Compared to other fire behavior fuel hazard models, FVS-FFE can simulate the dynamics of vegetation, including snags and surface fuels, as well as the interactions between these processes at a stand level.



The integrated components of the OptFuels system help fire and fuel managers access the data and multiple capabilities they need through one, easy-to-use interface.

- **FlamMap**—A spatial fire behavior modeling tool that helps generate fire behavior data that are comparable across a landscape for a given set of weather and/or fuel moisture data inputs. FlamMap also helps assess fuel hazard in terms of fire behavior.
- **Optimizer**—A heuristic process for scheduling patterns and timing of fuel treatments to minimize the expected loss from future wildland fire. The optimizer runs the Minimum Travel Time (fire spread) option within FlamMap at each iteration to evaluate expected loss.

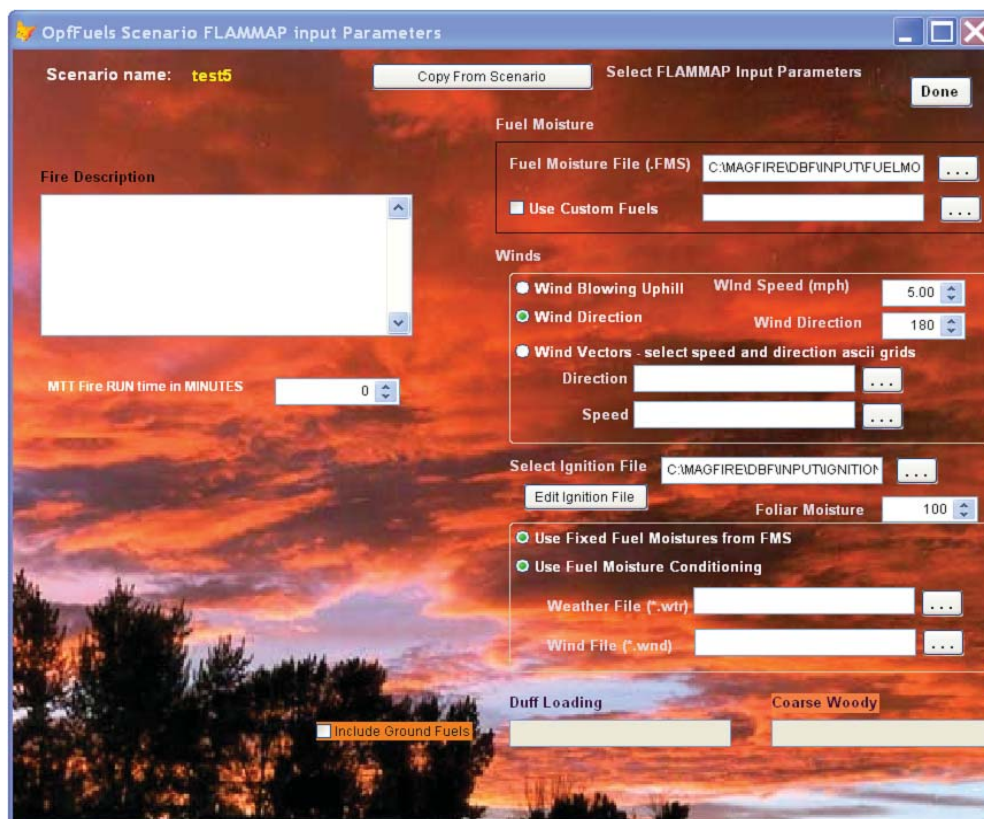
For the spatial component of OptFuels, users create geographic information system (GIS) stand polygons, or shapes that represent a specific area or stand. These stand polygons can also double as treatment unit polygons, helping eliminate the need to create separate polygons for each spatial area. Users then develop management regimes (comprised of one or more treatment activities such as thinning and prescribed burning) that are assigned to the polygons based on stand characteristics, land ownership, use restrictions, topography, or other GIS attributes. For example, mechanized thinning may be restricted in areas adjacent to streams. Each management regime is comprised of a sequence of treatment activities that may extend over multiple planning periods to represent scheduled retreatment of the same location, or represent a one-time treatment occurring in a single planning period. This capability was also intended to help users minimize the expected loss from potential future wildfires. Activity costs can be entered as a simple average or can vary by conditions where appropriate.

After the management regimes have been developed, OptFuels runs FVS-FFE to simulate the no action landscape. Management regimes are then assigned to the polygons based on the no-action stand characteristics and the geographically-defined management zones. The treatment activities

comprising the management regimes are then simulated with FVS-FFE. In this process, FVS-FFE is used to project both treated and untreated stands and compute the resulting fuel parameters for each planning period. Timber and non-merchantable material amounts can be recorded and used for developing resource management scenarios.

Once the OptFuels model is built, users can develop alternative treatment scenarios by specifying the fire scenario, including the wind direction and speed, the fuel moisture conditions, and ignition points, as well as assigning one or more optional constraints (such as acres to treat or treatment budget). OptFuels will then determine the location and timing of treatment activities that will have the greatest likelihood of minimizing expected loss from future fires across the planning area.

The OptFuels solution consists of treatment scheduling, the associated expected loss value, the amounts computed for the constraints, and the FlamMap fire behavior summary reports and FlamMap-ready landscape files for both the projected untreated and treated landscapes. These files can be useful for a variety of additional fire behavior analyses utilizing the solution results.



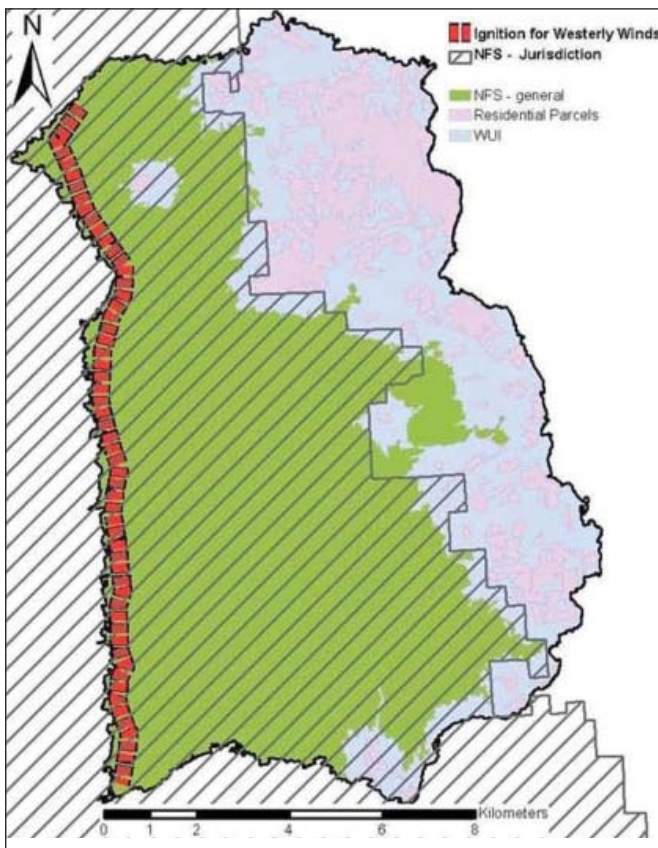
At this screen users can enter parameters for FlamMap that are used in scheduling treatments that minimize expected loss.

Testing two landscapes

Researchers tested OptFuels in two fuel treatment planning areas of the Bitterroot National Forest—the Trapper-Bunkhouse area and the Willow-Gird area.

Trapper-Bunkhouse

The Trapper-Bunkhouse area is west of Darby, MT and located on the west side of the Bitterroot Valley. At 34,000 acres, approximately 70 percent of the area is wildland urban interface (WUI). Throughout most of the area, the vegetation structure is overstocked, with dense stands that are at an increased risk of stand-replacing crown fires as well as insect infestations. According to fire regime condition class classifications, the fire behavior, vegetation structure, and fuel loads in this area are considered either highly or moderately departed from historical conditions. In addition, these existing fuel loads pose a threat to the natural resources, fire fighters, and the public, and, if multiple ignitions or sizable fires (larger than 100 acres) occur, suppression forces could be overwhelmed.

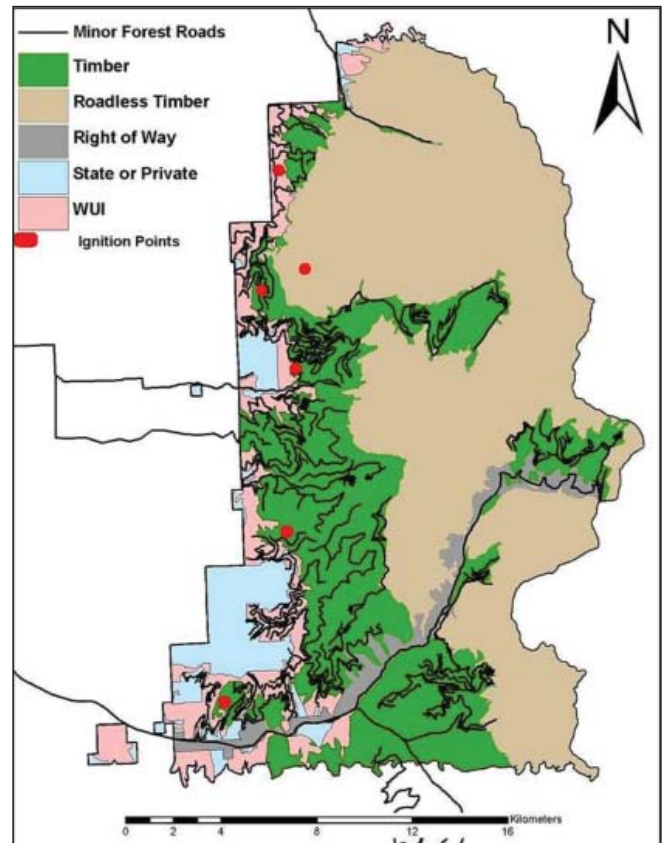


Value-at-risk categories are shown here for the Trapper-Bunkhouse study area. The fire scenario included a line of ignition on the west boundary of the study area with winds out of the west at 20 miles per hour.

Willow-Gird

On the northeast side of the Bitterroot Forest and straddling the Stevensville and Darby Ranger districts, Willow-Gird was the other testing area used in this study. The 103,689 acres are bordered on the west by the Bitterroot Valley and Corvallis, MT, with rapid development of

residential areas rising up between Corvallis and the national forest. The vegetation structure in the majority of the project area is very similar to Trapper-Bunkhouse, with overstocked, dense stands that are at a high risk of insect and disease attack. Restoration treatments are being considered here to help thin dense stands of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*) at lower elevations, and to regenerate native lodgepole pine (*Pinus contorta* var. *latifolia*) at higher elevations where there is an increased risk for stand-replacing fire because the stands are old and have a variety of insect and disease agents present, including an active mistletoe infestation.



To calculate expected loss for the Willow-Gird area, researchers used the values-at-risk categories shown here. Timber represents national forest acres that are without another risk category and right of way represents a power-line corridor. The fire scenario included six ignition points along the west boundary to represent human-ignited fires in the wildland urban interface.

Validations and concerns

Overall testing results of the OptFuels solution confirmed that it is possible to simultaneously schedule fuel treatments across multiple planning periods. Specifically for fuel treatment scenarios scheduled over two planning periods in the Trapper-Bunkhouse area, fire arrival time in the WUI/residential parcels was substantially increased. The average arrival time for no action was 2,422 minutes of fire spread. This was increased to 3,083 minutes when 10 percent of the potential fuel treatments are accomplished per period, 4,400 minutes when 20 percent

are accomplished, and 5,852 minutes when 25 percent are accomplished. This increase in fire arrival time reduces the potential for expected loss from future fires. The other factor that can reduce expected loss with fuel treatment is lower flame length.

In the Willow-Gird area, reductions in expected loss were less significant. The fire arrival time did increase for scheduled fuel treatments but was not changed enough to substantially reduce expected loss for landscape areas that had the highest values at risk, such as the WUI. Researchers felt that this was primarily due to the relative close proximity of the ignition points in the WUI (simulating human-ignited fires) and the values at risk, many of which were in the WUI.

Another important discovery was the lack of FVS-ready (stand) inventory data. Any planning process that uses FVS-FFE to estimate stand growth and predict fuel parameters for fire behavior modeling of future landscapes requires FVS-ready inventory data that represent each stand polygon in a planning area. These stand-level data were unavailable at the time of the study except in locations where tree lists had been assigned to stand polygons by previous studies. Therefore, in order to conduct this type of analysis, the inventory data was developed for each polygon by performing imputation, which substitutes missing data with similar existing data. For this project, researchers matched available inventory plots, such as Forest Inventory and Analysis (FIA) plots, with stand polygons. The imputation process was used several times for the two study areas, but with less than satisfactory results.

Jones commented, “In particular, the percent crown closures calculated for the imputed data were consistently much lower across the study area than the crown closure percentages predicted by two forest vegetation and fuels classification systems (R-1 V-Map and LANDFIRE) which the study team believed to be a better representation of the study area. These lower density representations of the stand polygons affected the FVS-FFE simulations and the resulting fuel parameters, both with and without treatment. This, in turn, affected the fire behavior modeling, which even with the severe fire conditions consistently predicted less severe fire for the untreated landscape than observed from recent past fires in the same general area. Recently I have heard that FIA is in the process of assigning tree lists to stand polygons. This would be an important development for the future use of these tools.”

Advantages of OptFuels

“This system provides managers the capability of developing a strategy for where, when, and how to apply fuel treatments on a landscape to achieve the most fuel

treatment benefit for given budgets while satisfying resource constraints,” said Jones.

OptFuels also helps managers:

- Plan fuel treatment locations and determine treatment effects across planning periods. As a result, treatments in the current period are selected for their current effectiveness in modifying fire behavior but also for their ongoing effectiveness in subsequent periods.
- Measure a variety of tradeoffs. This can include assessing differences in expected loss, arrival time, or flame length with different fuel treatments or evaluating how expected loss changes when a certain percentage of treatments are restricted to jointly achieve a specific objective (such as aspen restoration). Managers can also increase budget constraints to determine the additional fuel treatment benefits that can be achieved over time with increasing fuel treatment costs for a planning area.
- Estimate the volume and value of wood products and woody biomass produced by mechanical fuel treatments. This can also include the net value (revenue minus cost) of mechanical fuel treatments.

Recommendations for optimal use

To ensure that OptFuels is operating at its full potential, there are a few key recommendations to follow. First, it is important for managers to select effective fuel treatment options that can reduce undesired fire behavior, rate of spread, and/or flame length. This may seem obvious, however, it is a critical step worth emphasizing. Without effective treatment options to select from, the OptFuels solution will not be able to develop spatial fuel treatment schedules that provide the desired results managers are hoping for. Therefore, to help ensure the selection of effective fuel treatment options, researchers and developers suggest thoroughly testing both the treated and untreated stand fire behavior while selecting treatment options for use in OptFuels.

The second recommendation relates to the lack of FVS-ready inventory data issue that researchers encountered during the OptFuels testing process. To simulate vegetation, FVS-ready data are required. But these data are not readily available and the process of obtaining them can be quite technical and time consuming. Therefore, researchers request that managers support the ongoing development of FVS-ready data, such as the efforts by FIA or LANDFIRE.

GIS and other computer skills, such as basic knowledge of spreadsheets and the ability to view database files, are needed to operate OptFuels and the models employed by OptFuels.

GIS and other computer skills, such as basic knowledge of spreadsheets and the ability to view database files, are needed to operate OptFuels and the models employed by OptFuels. For that reason, researchers recommend supporting the development of these skills in the workforce.

Encouraging regular use of

OptFuels and corresponding models is also advised, as well as dedicating a substantial portion of a position to using these models (and/or by serving multiple zones or forests).

Fine-tuning and future plans

Currently, OptFuels is in the final testing and debugging mode and developers hope to have a downloadable version available within the next few months. The solution is undergoing a lot of fine-tuning, as developers rework the data for the two test areas.

The developers are currently collaborating with the developers of the Interagency Fuels Treatment Decision Support System (IFT-DSS) to discuss possible integration with OptFuels. IFT-DSS is an integrated Web platform that facilitates software such as OptFuels working with other fire and resource software and is expected to be available in the summer of 2011. OptFuels provides the essential risk analysis that is very difficult to do under current analysis capabilities.

In addition, developers are producing an OptFuels application for the Lake Tahoe basin. Future OptFuels enhancements may also include:

- Developing processes to help users prepare input data,
- Providing the ability to analyze the effectiveness of fuel treatment patterns on two or more fire conditions simultaneously,
- Integrating FARSITE into OptFuels to simulate fire behavior under varying fuel and weather conditions, and
- Analyzing the effects of treatment polygon size, or project area, on solution quality and efficiency.

Management Implications

- Ensure the selection of effective fuel treatment options by thoroughly testing both the treated and untreated stand fire behavior while selecting treatment options for use in OptFuels.
- Support the ongoing development of landscape GIS vegetation coverage with FVS-ready data.
- Provide user training in GIS and other computer technologies for both OptFuels and the models employed by OptFuels. Encouraging regular use of OptFuels is also highly recommended, which could be accomplished by dedicating a significant portion of a position to the use of OptFuels and related tools.

Further Information: Publications and Web Resources

OptFuels Project Website:

www.fs.fed.us/rm/human-dimensions/optfuels

OptFuels User Guide:

www.fs.fed.us/rm/human-dimensions/optfuels/downloads/OptFuelsUsersGuide.pdf

Scientist Profiles

Greg Jones is a Supervisory Research Forester with the Human Dimensions Program at the Rocky Mountain Research Station in Montana. Dr. Jones' research focuses on developing and testing methodology and models for applying economic analysis at both project and landscape scales. In recent years, he has concentrated on the economics of ecosystem management and planning, fire and hazardous fuel management, and utilization of biomass produced by forest fuel and restoration treatments.



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Woodam Chung is an Associate Professor of Forest Operations in the Department of Forest Management at The University of Montana. He was born in Seoul, South Korea and received his BS and MS in Forestry from Seoul National University, Korea. After he spent two years in Indonesia working in Forestry and Agriculture as an international volunteer, he came to Oregon and received his PhD in Forest Engineering from Oregon State University.



Dr. Chung teaches courses and conducts research in the fields of geographic information systems, forest roads, and forest management planning. He has been actively involved in the development of various decision-support systems designed for forest transportation planning, timber harvest scheduling, forest operations planning, invasive species management, and fire management.

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