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A Consumer Guide: Tools to Manage Vegetation and Fuels

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Abstract

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Current efforts to improve the scientific basis for fire management on public lands will benefit from more efficient transfer of technical information and tools that support planning, implementation, and effectiveness of vegetation and hazardous fuel treatments. The technical scope, complexity, and relevant spatial scale of analytical and decision-support tools differ considerably, which provides a challenge to resource managers and other users who want to select tools appropriate for a particular application. This publication provides a state-of-science summary of tools currently available for management of vegetation and fuels. Detailed summaries include a description of each tool, location where it can be obtained, relevant spatial scale, level of user knowledge required, data requirements, model outputs, application in fuel treatments, linkage to other tools, and availability of training and support. Streamlined summaries in tabular format allow users to rapidly identify those tools that could potentially be applied to a specific management need. In addition, an interdisciplinary team process is described that facilitates application of tools and decisionmaking at different spatial scales.

Keywords: Decision support, fire management, fuel treatment, hazardous fuel.

Contents

Introduction–Science-Based Vegetation and Fuels Planning

Resource managers need strategies to reduce fuel loadings and retain resilience to future fire and other disturbances, because fire exclusion has altered the structure and function of dry forest and rangeland ecosystems in the interior Western United States. A scientific foundation and technical support are needed for the development of consistent, long-term strategic plans for fuel and vegetation treatments (hereafter referred to as "fuel treatments") for all spatial scales and planning units. The plans are typically a component of fire management plans, national forest plans, and other planning documents, and should be compatible with national, regional, and local strategies for fuel treatments and other aspects of resource management.

Scientific and technical support provides principles and tools that inform management decisions regarding fuel treatments, contribute to the application of best management practices, and support the spatial and temporal placement of treatments to facilitate management effectiveness and attainment of desired future conditions. Credible science-based fuel treatment includes:

- **A consistent decision process** for identifying and planning fuel treatments.
- **High-quality data** for landscapes where treatments are proposed.
- **An accountability process** including long-term monitoring for documenting and evaluating treatments.

Consistent Decision Process

Management-science collaboration—
An effective collaborative approach for decisionmaking is an interdisciplinary (ID) team consisting of (1) local resource specialists from a large management unit (e.g., national forest, ranger district, Bureau of Land Management [BLM] district, national park, or wildlife refuge), (2) one or more resource specialists from an administrative office (e.g., Forest Service regional office, BLM state office), (3) one or more research scientists, (4) local stakeholders if there is sufficient interest (e.g., municipal officials, business representatives, nongovernmental organizations), and (5) a facilitator. It is helpful to have technical specialists in fire, vegetation management, wildlife, soils, and hydrology, although this may not always be possible. It is also desirable to have expertise in planning and National Environmental Policy Act (NEPA) processes, as well as a higher level manager or someone on the team with clear decisionmaking authority. Some teams may also want to include

expertise in economics and social science. This is an ideal team composition that may not always be attainable.

Primary responsibilities of the ID team are listed below:

ID team member	Responsibilities
Local resource specialists	Geospatial databases (fuel and vegetation data, historical fire occurrence, wildlife, hydrology), natural resource expertise, management objectives and desired conditions (watershed protection, resource values, etc.), guidance on local regulatory and political issues (threatened and endangered species, air quality, etc.)
Resource specialists from an administrative office	Administration of consistent ID team process, guidance on national and regional regulatory policy issues, NEPA guidance, natural resource expertise.
Research scientists	Expertise in natural resource science, capability in modeling and decision support, contribution of relevant data, document review, consistent application of science among administrative units, on-going scientific consultation.
Local stakeholders	Collaboration with local residents and businesses; identification of economic, esthetic, and environmental concerns.
Facilitator	Facilitation of efficient and productive ID team meetings, documentation and reporting of proceedings, communication among ID team members.

Scale-based decision framework—

Decisions about vegetation and fuels planning differ according to spatial scale and are prompted by different issues and decision criteria. Most available information and analyses have been developed for application at smaller spatial scales, and it is often not appropriate to scale up to broader spatial scales. Scaling up information, analyses, and decisions can be done, but only with the knowledge that error (or larger confidence intervals) will likely be introduced into quantitative and qualitative aspects of decisionmaking.

Relevant scale-based questions include:

One to a few forest or range sites—

- What is the potential for unplanned fire with unacceptable results or costs?
- What are desired fire behavior and fire effects, and which fuels should be removed to attain them?
- Which kinds and spatial arrangement of treatments will most effectively modify fire behavior, allow fire to be successfully suppressed, and attain desired conditions for multiple resource objectives?
- What are specific options for fuel treatments and the quantitative and qualitative costs/benefits associated with each?
- What is the expected duration of effectiveness for each fuel treatment?
- Which logistic considerations and risks must be addressed to successfully conduct the fuel treatment?

Small to moderate watersheds (approximately 5^{th}- to 6^{th}-field hydrologic unit code [HUC])—

- Which stands or groups of stands are at highest risk for crown fire or large, homogeneous burns owing to fuel accumulation?
- Which resources (habitat, structures, water quality, etc.) are at high risk from fire owing to fuel accumulation?
- Which locations, if treated, will allow the creation of fuel conditions that facilitate successful fire suppression?
- Where are fuel treatment options limited or restricted owing to administrative prohibitions, limited access, high risk, or low probability of success?

Large watershed (approximately 4^{th}-field HUC) to national forest or BLM district—

- Which resources (e.g., habitat, water quality) and other assets (e.g., buildings, communication facilities) are at high risk from fire owing to fuel accumulation and require priority allocation of effort?
- Which locations provide the greatest strategic opportunity for fuel treatments that would facilitate attainment of desired conditions (e.g., reduce large-scale fire hazard, facilitate successful fire suppression)?
- Do opportunities exist for long-term biomass utilization and other sustainable means of revenue production?
- Where are fuel treatment options limited or restricted owing to administrative prohibitions, limited access, high risk, or low probability of success?

The ID team needs to consider which decision systems and tools are most appropriate for informing the decision process at each spatial scale. The focus of fuel treatment is typically on reducing hazardous surface fuel and crown fire hazard, but consideration also needs to be given to how the fuel treatment will affect other vegetation, wildlife, aquatic resources, and economic values.

A decision framework—
A NEPA analysis or similar type of decision framework is required for many aspects of forest and rangeland management, including fuel and vegetation treatments. The decision framework below can be used as a point of departure for the analysis of individual fuel treatments, as well as broad-scale fuel treatments across forest and rangeland landscapes.

Desired conditions can be clearly defined for fuel treatments at all spatial scales for which treatments are considered. Attainment of these conditions normally requires:

- Reduced fuel loadings in locations that currently have heavy accumulations of hazardous fuels (including reduction in fire regime condition class).
- Reduced potential for crown fire, intense surface fire, and undesirable fire effects on vegetation and other resources.
- Reduced potential for adverse fire effects on local communities and structures.
- A general desire for more heterogeneity of vegetation across the landscape.

Consequences of fuel treatments, including long-term and short-term outcomes, can be evaluated through a series of questions for alternative fuel treatment options, such as:

Wildfire

- What are the effects on crown fire hazard?
- What are the effects on surface fire hazard?
- Can future fires be suppressed when necessary?
- At what interval will fuels need to be treated in the future? What kinds of treatments will be needed?
- What are the cumulative effects of multiple treatments on wildfire potential?

Vegetation

- What are the effects on large trees and snags?
- What are the effects on the vegetation desired to be left following treatment?
- What are the effects (positive and negative) on special-status plant species?
- What are the effects on exotic species?
- What patterns of plant communities, habitats, and structures will develop?

Wildlife

- What are the effects on critical habitat structures and animal populations?
- What are the effects (positive and negative) on special-status animal species?
- What patterns of animal habitat will develop through time?

Aquatic systems and water

- What are the effects on water quality?
- What are the effects on water yield?
- What are the effects on fish habitat?
- What are the effects on riparian systems?

Soils

- What are the effects on sediment production and delivery?
- What are the effects on soil fertility and long-term productivity?
- What are the effects on large woody debris and soil organic matter?

Air

- What are the effects on production of particulates and gases?
- What are the effects on mandatory Class 1 areas, designated nonattainment areas, and air quality management areas?
- What are the downwind smoke effects from prescribed fires?
- What are threats to air quality if no action is taken?

Cultural resources

- What are the effects on archeological sites and other cultural resources?

Local community involvement

- Are there opportunities for collaboration with local citizens (scoping notices and letters of response vs. full involvement, e.g. Community Wildfire Protection Plan, selection of watersheds for treatment)?
- What are the effects on recreational activities (camping, hiking, hunting, etc.)?
- What are the effects on commodity values (wood products, grazing, special forest products [e.g., mushrooms and berries])?

Economics

- What is the economic cost of the proposed treatment?
- What is the potential economic benefit of the proposed plan for the federal government?
- What is the potential economic benefit to employment and revenue in local communities?
- What kinds of contracts and institutional arrangements can be used?

Health and safety

- What are the effects on health and safety of people in local communities?
- What are the effects on health and safety of federal employees, contractors, and firefighters?

Regulatory

- Is any significant legislation or policy, including the Healthy Forests Restoration Act (HFRA), relevant to the proposed plan?
- Which local governmental units will be affected?
- Which local organizations, institutions, and individuals need to be informed of the proposed plan?

Most of these categories and questions can be applied to most scales at which fuel treatment planning is done. Other categories and questions can be added to ensure that specific needs are addressed.

ID team process—

Interactive evaluation of fuel treatment alternatives and fire spread is a key to successful synthesis of existing information and elicitation of expert knowledge. Map-based evaluation of alternatives should focus primarily on spatial patterns with respect to existing fuel and vegetation, likely ignition sources, potential fire spread, fire suppression strategy, fire effects, and future resource conditions.

Simulation models such as FARSITE can be used to quantify potential fire, although individual ID teams need to decide if they have sufficient technical capability to reliably run simulation models. Expert opinion of local fire managers is extremely valuable in estimating large-scale fire behavior and fire patterns, and is typically sufficient for good decisionmaking in the absence of fire-spread modeling.

Spatial patterns of fuel treatments that effectively reduce or modify fire spread across large landscapes are of considerable interest, because this information is needed to develop long-term spatial strategies for fuel treatment and other aspects of resource management. At present, empirical data on which to base optimization of spatial patterns are sparse, and the scientific basis for addressing fuel placement across complex landscapes is minimal. However, testing by resource managers of strategic placement of treatments will add data in the years ahead and provide information that can be shared and applied in other locations.

Elimination rules are criteria that exclude portions of the landscape where fuel treatments are unlikely; these might include steep slopes, riparian areas, higher elevation forests with high fuel moistures, other ownerships where treatments are not desired, and areas with sparse fuels. Removing these locations from consideration reduces the area where fuel treatment is evaluated and constrains the pattern of fuel treatment options, although the eliminated locations can still affect (and be affected by) how treatments influence fire patterns.

Fire spread is an important analytical focus for landscapes of any size, but other fire effects (e.g., residual fuels, smoke emissions, air quality) should be evaluated concurrently in order to assess the effects of fire on as many ecological, social, and economic factors as possible.

High-Quality Data

Accurate geographic information system (GIS) coverages of fuel properties are the key geospatial data needed by the ID team assessing fuel treatment strategies. Subsequent analysis and modeling have little value in the absence of high-quality fuels data, leading to a “garbage in–garbage out” situation. Data quality differs considerably among management units. It is ideal to have as much actual fuelbed information as possible, and collection of new and accurate empirical data is encouraged. Some units have mapped stylized fuel models, which provide a low-resolution classification of surface fire behavior adequate for current fire spread modeling, but quantification of both surface and crown fuels is necessary to capture a realistic picture of fire hazard. This can be derived from the Fuel Characteristic Classification System (FCCS) data library (see tool summaries), whose default fuel loadings can be modified by users as needed, or from the Photo Series for Natural Fuels (see “Stereo photo series” in tool summaries) available for different vegetation types. In some cases, existing vegetation classifications and other management data (e.g., stand inventory) can be used to infer fuel properties (e.g., LANDFIRE; see tool summaries). In some cases, aerial photography, satellite imagery, and LIDAR imagery may be available for classifying vegetation and fuel; remote sensing experts should be consulted about imagery-based inferences. Expert knowledge is a key input to any approach used to characterize fuel properties for a given landscape.

The required accuracy and resolution of fuel data depend on the scale of application of those data. For stands and individual projects, accurate high-resolution data are needed in order to develop appropriate fuel treatment alternatives. Onsite data collection and validation of fuel properties are highly desirable. The Photo Series for Natural Fuels and similar guides can be useful for rapid yet accurate assessment of fuelbed properties. For large watersheds and national forests or BLM districts, more generic fuel classifications are sufficient, and classifications from remote sensing imagery may be useful.

The ID team should direct the assessment of existing data, collection of new data, and development of appropriate classifications. Cooperation between fuel specialists and research (e.g., Forest Service or U.S. Geological Survey research station) scientists can be especially helpful in developing accurate maps. The ID team should state criteria for data quality on any given management unit, and agree on how much time and budget should be allocated toward compilation of the fuel database. It will be difficult to have consistent quality among all management units within a large region because of the different types of data available. Derivation of the data should be documented and scientifically defensible, regardless of the accuracy and resolution of final databases.

Accountability Process

Accountability is required by the HFRA for fuel treatment programs and is a logical component of science-based management. Quantification of the outcomes of fuel treatment programs is needed to provide feedback to the adaptive management process, so that long-term decisionmaking and planning can be continually improved.

Three types of fuel treatment monitoring will ensure short-term and long-term accountability: (1) implementation monitoring, (2) effectiveness monitoring, and (3) validation monitoring. Monitoring is implemented as follows:

Implementation monitoring–When, where, and how are treatments conducted?

Treatments can be tracked in a database for appropriate management units (e.g., national forest or BLM district). The date, location, area, kind of treatments, and lead personnel should be included at a minimum. Some of this information is currently being captured by federal agencies in various cumulative databases. Accurate data on thinning prescriptions, burning prescriptions, and surface fuel treatments are especially valuable. It is critical that all treatments are accurately georeferenced so they can be included in GIS coverages compatible with other coverages for a given management unit and adjacent lands. (In the Forest Service, this would typically be the responsibility of regions and national forests; in the BLM, it would be the responsibility of state offices and districts and field offices.)

Effectiveness monitoring–What change in condition of fuels and other resources was attained?

Quantifying the condition of fuels and other relevant resources before and after treatments is the best way to determine the effectiveness of treatments. Although HFRA requires only a representative sample, **monitoring 100 percent of treatments is the most credible approach to documenting effectiveness**. At a minimum, alterations in surface fuel, canopy fuel, woody fuel, and plant community structure should be quantified. Periodic posttreatment monitoring is needed to quantify temporal changes in fuels, plant community structure, plant species composition, wildlife habitat, erosion, and hydrology; the interval for subsequent measurements will differ by resource. (In the Forest Service, this would typically be the responsibility of national forests; in the BLM, it is the responsibility of districts and field offices)

Validation monitoring–Did the treatment accomplish objectives for desired conditions?

Long-term performance of fuel treatments with respect to attainment of desired conditions must be documented to achieve full accountability. For example, if a crown fire drops to a surface fire (under severe weather conditions), the treatment could be considered successful; if a crown fire is not impeded, the treatment could be considered unsuccessful. Other resource objectives for vegetation, wildlife, and hydrology can also be assessed. Validation is best tracked through a GIS database in which wildfire locations and fire effects (e.g., severity classes in terms of tree mortality) are overlain on fuel treatment locations. The number of validations in the empirical database will increase over time as fire data accumulate, providing feedback to adaptive management. (In the Forest Service, this would typically be the responsibility of regions and possibly research stations; in the BLM, it would be the responsibility of state offices).

Adaptive Learning Through Collaboration

The efficiency and value of collaboration improves with experience. Similarly, the quantitative rigor and consistency of specific applications improve as methods are refined through iterations on multiple management units. It is anticipated that current efforts in fuel planning will grow from case studies and demonstrations to an institutionalized collaboration between management and research.

Adaptive management of fuels is more likely to be successful if all three types of monitoring occur. Empirical data, rather than observational and anecdotal information, are needed to improve fuel management at all spatial scales. These data and learning experiences should be communicated to resource managers in a timely way through scientific publications, reports, and meetings. Natural resource staffs in regional administrative units have the responsibility to ensure that technical communication occurs and that the best available science is available to land managers.

If sufficient progress is made in developing successful fuel treatment programs–including science-based planning documentation and on-the-ground applications–good approaches for fuel planning will emerge and be emulated. It will then be possible for each management unit to be responsible for its own ID team process, with nominal oversight by regional administration, and consultation from scientists only as requested. However, review by regional specialists and scientists is advisable to provide quality control for planning documents.

What Is Contained in This Guide?

This publication provides summaries of software, simulation models, and decision-support tools that may be useful for planning and implementing the management of vegetation and hazardous fuels. These products have been developed over the past 30 years by scientists and managers involved in different areas of resource assessment that require at least some interaction with fire. Succinct descriptions allow users to quickly review the potential applicability of various tools for a particular management situation.

A key aspect of the publication is the identification of appropriate scope and spatial scale for specific applications of analytical and decision-support tools. Some tools have been developed for specific purposes but can be extrapolated to other tasks with the appropriate caveats. Similarly, some tools have been developed for specific scales (e.g., forest stands) but can be cautiously applied to larger scales (e.g., watersheds) in the absence of other tools. All of the tools described here are intended to guide decisionmaking, rather than provide definitive answers. Expert judgment is nearly always needed to fill in data gaps and to address perceived lack of accuracy or precision.

Why Are the Summaries of Tools Needed?

Federal land managers are required to develop science-based approaches and to use the best available science to generate management pathways for desired conditions of resources. The variety of scientific software, simulation models, and decision-support tools available for hazardous fuel treatment can be overwhelming, even for an experienced scientist or resource manager. Effective use of any given tool typically requires considerable time, training, and sometimes expense. Some tools have been effectively institutionalized and supported by federal agencies, whereas other potentially useful tools have not, and development of new tools is ongoing. Judging the best available science can be facilitated by the use of objective descriptions and criteria included in this publication. If information beyond the summaries provided here is needed, users can consult the technical documentation listed in the summaries for more detail.

How Were the Summaries of Tools Developed?

An initial list of analytical and decision-support tools relevant for management of vegetation and hazardous fuel was developed in consultation with scientists in the Forest Service Pacific Northwest and Rocky Mountain Research Stations, and resource managers in the Forest Service Pacific Northwest Region and Oregon BLM. Some of these tools have been used routinely for many years, and applications are described in the scientific literature and management documents. Other tools have been used less frequently, and still others are only now being tested.

Identifying tools directly applicable to management of fuels and fire was relatively straightforward. However, vegetation and fuel planning must consider a broad range of resource values potentially affected by fuel management, including vegetation, wildlife, hydrology, air pollution, and economics. A comprehensive summary of all tools relevant to this broader list of resources is beyond the scope of this publication.[1] Therefore, we identified tools for which analytical outputs could be used directly to calculate changes in resource condition. All tools listed here consider fire and fuels explicitly, although the strength of connections among fire, fuels, and other resources differs.

How Is Best Available Science Determined?

Several points should be considered in determining best available science for a particular application in vegetation and fuel management.

Keep Processes Objective and Credible

It is important to first determine the array of tools and principles available for a particular application. It is also important to know if a particular tool has been appropriately peer reviewed according to specific standards for the application of scientific tools in resource management on public lands (Federal Register 2002, Office of Management and Budget 2004). Many of the tools currently in use by federal agencies have not been objectively (and anonymously) peer reviewed and published in scientific outlets other than in-house federal series. User guides are helpful but do not imply scientific credibility. Lack of peer review does not mean that a tool or technique has no utility, but that it has lower scientific stature and does not meet the normal standard for scientific rigor. Documents that rely on tools and techniques without peer review are more likely to be successfully challenged through litigation. A short description of limitations and uncertainty associated with various tools and techniques is often appropriate.

Look for success stories. If you can identify cases in which tools have been successfully applied to a situation similar to yours, then you have a good recommendation for your application. This may be an actual management situation, or in the case of a recently developed tool, it could be a "beta test" or demonstration in which positive feedback was received. In either case, other users are available from whom you can obtain insight.

Consult With Experts

It can be helpful to directly contact the developer of a particular tool or technique for additional information and insight on principles and applications. If you are considering an application somewhat outside the original scope described for a

[1] We attempted to find information for as many analytical and decision-support tools as possible within a reasonable timeframe. We apologize to those individuals and or organizations whose efforts may have been excluded from this publication.

tool, get some feedback first. Although few tools are fully supported by technical personnel, there are often a few scientists and managers who are considered experts on the design and application of the tool. Seek them out for a consultation, and consider inviting them to work with you and your staff.

Compare Alternatives

Even if you have a preferred tool or approach for a particular application, it is usually best to compare it with other tools. Although no single model may be more "correct" than another, it is helpful to know the differences between approaches. You may need to defend the value of your preferred choice, and documentation of alternative approaches allows for ready comparison and development of rationale for your preferences.

Document the Selection Process

Take good notes as you go through the process of reviewing and selecting appropriate tools and approaches. Keep a file with appropriate documentation of publications, user guides, scientists consulted, managers consulted, etc. Having a structured approach to selecting the scientific tools you use will improve overall credibility of planning activities and proposed management actions.

Consult Outside Reviewers

After you have selected analytical and decision-support tools for your particular management application, have technical experts review any plans or reports that cite those tools. Reviewers can include scientists, managers, planners, and policymakers–basically anyone within the broader user community who has some technical knowledge about the tools and their application. Review comments will help you determine if your selection and use of tools are appropriate and if planning documentation contains sufficient justification.

Consult Potential Stakeholders

After you are confident that you have addressed relevant technical issues, it is often valuable to "preview" the approach with stakeholders who may be affected by your management actions. This requires you to use nontechnical language to explain and justify your selection. Straightforward graphics and tables are often the best way to convey your ideas to interested parties who do not have technical expertise in natural resources.

How Should Information in This Publication Be Used?

The analytical and decision-support tools summarized here have a variety of potential applications. Some of them may be directly applicable to operational aspects of fuel treatments, including silvicultural manipulations, surface fuel management, and applications of prescribed fire for burning and treatment of activity fuels. These are applications that do not necessarily require extensive review or a high level of detail for decisionmaking.

Many types of documents require detailed review at different levels, including public review. This includes land use plans, fire management plans, and some fuel treatment plans. It is particularly important that documentation associated with NEPA reporting, such as environmental impact statements and environmental analyses, have scientific credibility. This publication can be a source of potential tools and analytical approaches that can be considered as part of NEPA reporting and review relative to management of vegetation and fuels.

Finally, as you consider potential tools for specific applications, make sure that the spatial scale for which a tool was developed is a reasonable match for the spatial scale of the application. Failure to match scales can result in inaccurate assessments, particularly if tools are scaled beyond their range of reliability. Explicit statements about the scale of application and the appropriateness of a particular tool for that scale are essential. In addition, be aware of scale matches and mismatches when using multiple tools or addressing multiple resources. For example, one tool may accurately address fuel at the stand scale, and another tool may accurately address wildlife habitat at the watershed scale. This disparity in spatial scales should be acknowledged and discussed quantitatively if possible and qualitatively at a minimum.

Are Other Sources of Information Available?

An increasing number of analytical and decision-support tools are now available on the Internet. For example, a number of analytical and modeling tools are available at Web sites maintained by the Forest Service Pacific Wildland Fire Sciences Laboratory (USDA Forest Service 2004a, 2004b), Rocky Mountain Research Station and Systems for Environmental Management (USDA Forest Service 2004c), and the University of Idaho (2004). These Web sites help ensure that users have the most recent version of any particular tool. The quantity and quality of documentation differs, but user guides and other descriptive information can usually be accessed through these sites. Technical support is usually minimal but is available in some cases. Interested readers are encouraged to visit these sites if they want detailed information beyond the summaries presented here.

How Can a Set of Tools Be Integrated for Vegetation and Fuels Planning?

The number and complexity of analytical and decision-support tools are a mixed blessing. On one hand, scientists have invested significant effort in developing approaches for vegetation and hazardous fuels planning (see app. 1), and users have lots of choices. On the other hand, it is challenging for resource specialists and planners to identify the tools that are most accurate and appropriate for a particular management issue and to stay informed about new research and development. Tools are often regarded as a "black box" whose function is poorly understood by users, and resource specialists typically have "favorite" tools, so it is difficult to have consistency in application of tools among different organizational units.

Spatial scale provides a logical framework for identifying appropriate tools (tables 1 and 2) and sets of tools that can be used for vegetation and fuels planning. For example, a set of tools recently developed by the Forest Service provides decision support for management of dry forests in the interior West **at the forest-stand scale**, including (1) *Armillaria* Response Tool, (2) *Guide to Fuel Treatment in Dry Forests of the Western United States* (Johnson et al. 2006), (3) My Fuel Treatment Planner, (4) Smoke Information System (not included in this publication), (5) Understory Response Model, (6) Water Erosion Prediction Project Fuel Management Tool, and (6) Wildlife Habitat Response Model. Unfortunately, tools are sometimes applied to scales beyond which they are considered reliable, or model output is scaled up or down without attention to reduced accuracy and increased error.

The examples below illustrate how multiple tools can be effectively used for fuel planning at different spatial scales (see examples below). Other criteria, including the level of knowledge required by a user (table 3) and amount of data required to use a tool (table 4), may also be practical considerations in identifying an appropriate tool or set of tools for a particular analysis.

Example 1–One to a Few Forest Stands

As part of an Environmental Impact Statement, the Twisp Ranger District of the Okanogan-Wenatchee National Forest needs to consider alternative fuel treatments for a management unit that consists of five 80-acre stands of mixed ponderosa pine

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Table 1—Summary of tools and models for hazardous fuel management, organized alphabetically

Tool name	Application	Spatial scale[a]	Analyst requirement[b]	Data requirements[c]	Link to other tools	Current status
Armillaria Response Tool (ART)	Estimates *Armillaria* root disease risk in dry forests	Small to medium	Moderate knowledge of forest ecology	Low and mostly qualitative	None	Available
BehavePlus	Predicts surface fire behavior properties	Small	Low, but typically requires specialized training	Low	Used in most other fire behavior tools	Available
BlueSky Smoke Forecast System (BlueSky)	Predicts surface smoke concentrations from prescribed burning and wildfires	Very large	Moderate; knowledge of smoke dispersion, meteorology, and fire helpful	Moderate; some default data available	BlueSky framework links CALPUFF, Consume, FASTRACS, FCCS, FEPS, HYSPLIT, MM5, NFDRS	Available
Comparative Risk Assessment in Fire and Fuels Planning (CRAFT)	Calcuates relative risks and tradeoffs of scenarios, and identifies variables with the greatest influence	Large	Moderate; helps to have expertise in decisionmaking with multiple options	Low	BehavePlus, Farsite, FVS	Development ongoing
Consume 3.0	Predicts fuel consumption and emissions during wildland fires	Small to medium	Relatively low; requires knowledge of Microsoft Windows[d] applications	Moderate; default values can be used if needed	BlueSky, FCCS	Available
Fire Area Spread Simulator (FARSITE/Flam Map)	Calculates fire spread and fire behavior properties	Medium to large	High; typically requires specialized training and knowledge of GIS	High; data often unavailable or difficult to obtain	FlamMap	Available
Fire Behavior Assessment Tool (FBAT)	Designing and prioritizing hazardous fuel treatments; evaluating the effectiveness of proposed treatments	Small	Low	Low	FlamMap2, LANDFIRE	Beta version being tested
Fire Ecology Assessment Tool (FEAT)	Storing, managing, and analyzing National Park Service fire effects monitoring data	Small to medium	Low	High	Replaces NPS Fire Monitoring Handbook	Available
Fire Effects Information System (FEIS)	Provides background on the potential effects of fire on flora and fauna	Small to very large	Low	Low	None	Available
Fire Effects Planning Framework (FEPF)	Identifies areas where fire may be beneficial or detrimental with respect to fire behavior and other management objectives	Small to medium	Moderate	High	FFE-FVS, FlamMap, FOFEM, URM, WHRM	

Table 1—Summary of tools and models for hazardous fuel management, organized alphabetically (continued)

Tool name	Application	Spatial scale[a]	Analyst requirement[b]	Data requirements[c]	Link to other tools	Current status
Fire Effects Tradeoff Model (FETM)	Simulates effects of land management and disturbance; calculates wildfire and fuel treatment area, emissions, economic value	Moderate to large	Moderate; GIS knowledge helpful	Moderate to high	BehavePlus, Consume, FCCS	Available
Fire Emission Production Simulator (FEPS)	Simulates fuel consumption, emission production, and plume buoyancy for fires	Small to medium	Relatively low; requires knowledge of Microsoft Windows applications	Moderate; default values can be used if needed	BlueSky, FCCS	Available
Fire Family Plus	Analyzes historical weather data	Medium to large	Moderate	Moderate	None	Available
Fire and Fuels Extension for the Forest Vegetation Simulator (FFE-FVS)	Calculates fuel properties, forest structure, surface fire behavior, crown-fire behavior and risk, fire effects	Small, but can be scaled up to larger scales with GIS	High	Moderate to high	FMA Plus	Available; good support through Forest Service
Fire Regime Condition Class (FRCC)	Classifies ecological status relative to historical fire and fuel conditions	Originally designed for large scale, but being applied at all scales; very coarse classifica- tions	Moderate	Moderate	None; difficult to link with other tools and classifications	Available
Fireshed Assessment	Designs and schedules fuel treatments to reduce fire spread	Medium to large	Moderate to high	High	ArcGIS tools, FARSITE, FFE-FVS, FlamMap, My Fuel Treatment Planner	Widely used in California; test mode elsewhere
First Order Fire Effects Model (FOFEM)	Calculates fuel consumption, emissions, tree mortality, soil heating	Small	Low	Low	None	Available
FlamMap	Calculates fire risk assessment	Medium	High	High	FARSITE	Version 2.0 available; version 3.0 in test mode

Table 1—Summary of tools and models for hazardous fuel management, organized alphabetically (continued)

Tool name	Application	Spatial scale[a]	Analyst requirement[b]	Data requirements[c]	Link to other tools	Current status
Forest Inventory and Analysis Biomass Summarization System (BioSum)	Assesses potential fuel treatments, costs, fire hazard, biomass production, products	Very large	High	High	FFE-FVS, Forest Inventory Analysis data, STHARVEST	Test mode; analyses available for some locations
Fuel Characteristic Classification System (FCCS)	Classifies and quantifies fuel properties and fire potentials	Small to large	Low	Low, although fuel and vegetation data improve accuracy; default values available	BehavePlus, FARSITE, Landfire	Available
Fuels Management Analyst Plus® (FMA Plus®)	Calculates crown fire risk, crown fuel characteristics	Small	Moderate	Moderate	Forest Vegetation Simulator	Available for moderate cost through private vendor
Gradient Nearest Neighbor Method (GNN)	Develops spatial database of vegetation and fuels	Medium to large	High; statistical and geospatial skills; some knowledge of satellite imagery	High, including field data, satellite imagery, GIS layers	FARSITE, FCCS, FlamMap, FFE-FVS	Several mapping projects completed; software in test mode
Guide to Fuel Treatments in Dry Forests	Displays quantitative and visual guidelines for fuel management, including silvicultural and surface fuel treatments	Small to medium	Low; knowledge of FFE-FVS improves understanding	Low	FCCS, FFE-FVS, Landscape Management System, My Fuel Treatment Planner	Available in 2006
Harvest Cost and Revenue Estimator (HCR Estimator)	Provides cost estimates for fuel treatment projects	Small	Low	Moderate	FVS	Beta version being tested
Integrated Forest Resource Management System (INFORMS)	Uses data from the FSVeg database grown forward by using the Forest Vegetation Simulator, including the Fire and Fuels Extension (FVS/FFE) for the current condition and each decade into the future up to 40 years for as many treatment alternatives as desired.	Small to medium	Low	Low	ArcView, FVS, Farsite, MSN, SVS	Currently installed at certain Forest Service sites; currently being developed to also run on Linux.

Table 1—Summary of tools and models for hazardous fuel management, organized alphabetically (continued)

Tool name	Application	Spatial scale[a]	Analyst requirement[b]	Data requirements[c]	Link to other tools	Current status
LANDFIRE	Develops spatial database of vegetation and fuels	Medium to large	Low to moderate	Moderate to high	FRCC	In development
LANDIS and LANDIS-II	Simulates multiple interacting disturbances	Medium to large	Moderate	Moderate	APACK, IAN, FRAGSTATS, FARSITE, PnET-II	Available
Landscape Simulator	Simulates landscape elements driving channel dynamics, including fire, geomorphic activity, and sediment routing	Small to large	High	High	None	In development
My Fuel Treatment Planner	Calculates cost and revenue information for fuel treatments	Small	Low to moderate	Low to moderate	My Fuel Treatment Guidebook	Available
NEXUS	Calculates crown fire risk	Small	Moderate	Moderate	None	Available
Optimizing Fuel Solutions and Ecological Values in Landscapes (FUELSOLVE)	Optimizes quantity and pattern of fuel treatments, with focus on “firesafe” landscapes and retention of preferred habitat	Medium	Moderate to high	Moderate to high	FARSITE, FCCS, FlamMap	In development
Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)	Generates probably maps of disturbance processes and vegetation attributes from multiple scenarios	Small to very large	Low	Moderate	FVS, Farsite, MAGIS, SPECTRUM, FRAGSTATS, PRMS	Available for the FS Northern Region, Sierra Nevada, and southern California, Gila NF, south-central AK, southwest UT, and the Colorado Front Range
Smoke Impact Spreadsheet Model (SIS)	SIS evaluates smoke impacts of different wildland burning scenarios for all vegetation types in the United States	Small	Low	Low	FOFEM, Consume, CALPUFF	Available
Stereo photo series for quantifying natural fuel	Estimates fuel and stand condition for predicting fuel consumption smoke production, fire behavior, and fire effects	Small to medium	Low	Low	Consume 3.0, FCCS, FOFEM, FEPS	11 volumes available for different vegetation and fuel types; 6 volumes in progress

Table 1—Summary of tools and models for hazardous fuel management, organized alphabetically (continued)

Tool name	Application	Spatial scale[a]	Analyst requirement[b]	Data requirements[c]	Link to other tools	Current status
Tool for Exploratory Landscape Scenario Analysis (TELSA)	Simulates interactions of vegetation, management, and disturbance (spatial)	Medium to large	Moderate	Moderate to high	FVS, VDDT (directly linked)	Available
Understory Response Model (URM)	Predicts impacts of specific fuel treatments on Plan species	Small	Low	Low	FFE-FVS, FOFEM, WHRM	Available
Valuation of Ecosystem Restoration Strategies (VERSTRA)	Calculates product potential and value for fuel treatments	Medium to large	Low to moderate	Low to moderate	FVS, Landscape Visualization System, VDDT	Test mode
Vegetation Dynamics Development Tool (VDDT)	Simulates interactions of vegetation, management, and disturbance (nonspatial)	Medium to large	Low to moderate	Moderate to high	FVS, TELSA (directly linked)	Available
Water Erosion Prediction Project (WEPP) Fuel Management (FuMe) Tool	Estimates sediment generated by fuel management activities	Small	Low	Low	None	Available
Wildlife Habitat Response Model (WHRM)	Evaluates effects of alternative fuel treatments on terrestrial wildlife habitats of dry interior forests	Small	Low	Low	FFE-FVS	Available

[a] Spatial scale:
Small–Forest stands to small watersheds, e.g., 6th-field hydrologic unit code (about 1 to 1,000 acres).
Medium–Moderate to large watersheds, e.g., 5th-field HUC (about 1,000 to 100,000 acres).
Large–Very large watersheds, ranger districts, national forests, e.g., 4th-field HUC (about 100,000 to 2 million acres).
Very large–Multiple national forests to regions (greater than 2 million acres).

[b] Analyst requirement:
Low–Resource specialist or local GIS specialist can run the model or tool locally with minimal changes needed for local situation.
Moderate–Requires a midlevel analyst or GIS specialist to run the model or tool or make it usable for local situations.
High–Requires a high-level analyst or programmer to run the model or tool or make it usable for local situations.

[c] Data requirement:
Low–Requires base resource data readily available at the regional or local level.
Moderate–Requires some specialized data in addition to the base resource data readily available at the regional or local level.
High–Requires specialized data and formats that will take a major commitment of resources to compile.

[d] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Table 2—Summary of tools and models for hazardous fuel management, organized by spatial scale

Spatial scale[a]	Tool name
Small	*Armillaria* Response Tool (ART)
	BehavePlus
	Consume 3.0
	Fire Behavior Assessment Tool (FBAT)
	Fire Ecology Assessment Tool (FEAT)
	Fire Effects Information System (FEIS)
	Fire Effects Planning Framework (FEPF)
	Fire Emission Production Simulator (FEPS)
	Fire and Fuels Extension for the Forest Vegetation Simulator (FFE-FVS)
	Fire Regime Condition Class (FRCC)
	First Order Fire Effects Model (FOFEM)
	Fuel Characteristic Classification System (FCCS)
	Fuels Management Analyst Plus® (FMA Plus®)
	Harvest Cost and Revenue Estimator (HCR Estimator)
	Integrated Forest Resource Management System (INFORMS)
	Landscape Simulator
	My Fuel Treatment Planner (MyFTP)
	NEXUS
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)
	Smoke Impact Spreadsheet Model (SIS)
	Stereo photo series for quantifying natural fuels
	Understory Response Model (URM)
	Water Erosion Prediction Project (WEPP) Fuel Management (FuMe) Tool
	Wildlife Habitat Response Model (WHRM)
Medium	*Armillaria* Response Tool (ART)
	Consume 3.0
	Fire Area Spread Simulator (FARSITE)
	Fire Ecology Assessment Tool (FEAT)
	Fire Effects Information System (FEIS)
	Fire Effects Planning Framework (FEPF)
	Fire Effects Tradeoff Model (FETM)
	Fire Emission Production Simulator (FEPS)
	Fire Family Plus
	Fire Regime Condition Class (FRCC)
	Fireshed Assessment
	FlamMap
	Fuel Characteristic Classification System (FCCS)
	Gradient Nearest Neighbor Method (GNN)
	Guide to Fuel Treatments in Dry Forests
	Integrated Forest Management System (INFORMS)
	LANDFIRE
	LANDIS and LANDIS-II
	Landscape Simulator
	Optimizing Fuel Solutions and Ecological Values in Landscapes (FUELSOLVE)
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)
	Stereo photo series for quantifying natural fuels
	Tool for Exploratory Landscape Exploratory Analysis (TELSA)
	Valuation of Ecosystem Restoration Strategies (VERSTRA)
	Vegetation Dynamics Development Tool (VDDT)

Table 2—Summary of tools and models for hazardous fuel management, organized by spatial scale (continued)

Spatial scale[a]	Tool name
Large	Comparative Risk Assessment in Fire and Fuels Planning (CRAFT)
	Fire Area Spread Simulator (FARSITE)
	Fire Effects Information System (FEIS)
	Fire Effects Tradeoff Model (FETM)
	Fire Family Plus
	Fire Regime Condition Class (FRCC)
	Fireshed Assessment
	Fuel Characteristic Classification System (FCCS)
	Gradient Nearest Neighbor Method (GNN)
	LANDFIRE
	LANDIS and LANDIS-II
	Landscape Simulator
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)
	Tool for Exploratory Landscape Scenario Analysis (TELSA)
	Valuation of Ecosystem Restoration Strategies (VERSTRA)
	Vegetation Dynamics Development Tool (VDDT)
Very large	BlueSky
	Fire Effects Information System (FEIS)
	Fire Regime Condition Class (FRCC)
	FIA BioSum
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)

[a] Spatial scale:
Small–Forest stands to small watersheds, e.g. 6th-field hydrologic unit code (about 1 to 1,000 acres).
Medium–Moderate to large watersheds, e.g., 5th-field HUC (about 1,000 to 100,000 acres).
Large–Very large watersheds, ranger districts, national forests, e.g., 4th-field HUC (about 100,000 to 2 million acres).
Very large–Multiple national forests to regions (greater than 2 million acres).

Table 3—Summary of tools and models for hazardous fuel management, organized by analyst requirement

Analyst requirement[a]	Tool name
Low	BehavePlus
	Consume 3.0
	Fire Behavior Assessment Tool (FBAT)
	Fire Ecology Assessment Tool (FEAT)
	Fire Effects Information System (FEIS)
	Fire Emission Production Simulator (FEPS)
	First Order Fire Effects Model (FOFEM)
	Fuel Characteristic Classification System (FCCS)
	Guide to Fuel Treatments in Dry Forests
	Harvest Cost and Revenue Estimator (HCR Estimator)
	Integrated Forest Resource Management System (INFORMS)
	LANDFIRE
	My Fuel Treatment Planner (MyFTP)
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)
	Smoke Impact Spreadsheet Model (SIS)
	Stereo photo series for quantifying natural fuels
	Understory Response Model (URM)
	Valuation of Ecosystem Restoration Strategies (VERSTRA)
	Vegetation Dynamics Development Tool (VDDT)
	Water Erosion Prediction Project (WEPP) Fuel Management (FuMe) Tool
	Wildlife Habitat Response Model (WHRM)
Moderate	*Armillaria* Response Tool (ART)
	BlueSky
	Comparative Risk Assessment in Fire and Fuels Planning (CRAFT)
	Fire Effects Planning Framework (FEPF)
	Fire Effects Tradeoff Model (FETM)
	Fire Family Plus
	Fire Regime Condition Class (FRCC)
	Fireshed Assessment
	Fuels Management Analyst Plus® (FMA Plus®)
	LANDIS and LANDIS-II
	NEXUS
	Optimizing Fuel Solutions and Ecological Values in Landscapes (FUELSOLVE)
	Tool for Exploratory Landscape Scenario Analysis (TELSA)
High	FIA BioSum
	Fire Area Spread Simulator (FARSITE)
	Fire Effects Planning Framework (FEPF)
	Fire and Fuels Extension for the Forest Vegetation Simulator (FFE-FVS)
	FlamMap
	Gradient Nearest Neighbor Method (GNN)
	Landscape Simulator

[a] Analyst requirement:

Low–Resource specialist or local GIS specialist can run the model or tool locally with minimal changes needed for local situation.

Moderate–Requires a midlevel analyst or GIS specialist to run the model or tool or make it usable for local situations.

High–Requires a high-level analyst or programmer to run the model or tool or make it usable for local situations.

Table 4—Summary of tools and models for hazardous fuel management, organized by degree of data requirements

Data requirements[a]	Tool name
Low	*Armillaria* Response Tool (ART)
	BehavePlus
	Comparative Risk Assessment in Fire and Fuels Planning (CRAFT)
	Fire Behavior Assessment Tool (FBAT)
	Fire Effects Information System (FEIS)
	First Order Fire Effects Model (FOFEM)
	Fuel Characteristic Classification System (FCCS)
	Guide to Fuel Treatments in Dry Forests
	Integrated Forest Resource Management System (INFORMS)
	Smoke Impact Spreadsheet Model (SIS)
	Stereo photo series for quantifying natural fuels
	Valuation of Ecosystem Restoration Strategies (VERSTRA)
	Understory Response Model (URM)
	Water Erosion Prediction Project (WEPP) Fuel Management (FuMe) Tool
	Wildlife Habitat Response Model (WHRM)
Moderate	BlueSky
	Consume 3.0
	Fire Emission Production Simulator (FEPS)
	Fire Effects Tradeoff Model (FETM)
	Fire Family Plus
	Fire and Fuels Extension for the Forest Vegetation Simulator (FFE-FVS)
	Fire Regime Condition Class (FRCC)
	Fuels Management Analyst Plus® (FMA Plus®)
	Harvest Cost and Revenue Estimator (HCR Estimator)
	LANDFIRE
	LANDIS and LANDIS-II
	My Fuel Treatment Planner (MyFTP)
	NEXUS
	Optimizing Fuel Solutions and Ecological Values in Landscapes (FUELSOLVE)
	Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)
	Tool for Exploratory Landscape Scenario Analysis (TELSA)
	Vegetation Dynamics Development Tool (VDDT)
High	Fire Ecology Assessment Tool (FEAT)
	FIA BioSum
	Fire Area Spread Simulator (FARSITE)
	Fire Effects Planning Framework (FEPF)
	Fireshed Assessment
	FlamMap
	Gradient Nearest Neighbor Method (GNN)
	Landscape Simulator
	Understory Response Model (URM)

[a] Data requirements:

Low–Requires base resource data readily available at the regional or local level.

Moderate–Requires some specialized data in addition to the base resource data readily available at the regional or local level.

High–Requires specialized data and formats that will take a major commitment of resources to compile.

and Douglas-fir with high stem densities and heavy ladder fuels. The primary objective is to reduce crown fire hazard while providing high-quality habitat for deer and elk.

- Step 1. Consider using *Guide to Fuel Treatments in Dry Forests of the Western United States* (Johnson et al. 2006) to identify initial stand conditions similar to those in the management unit; both descriptive information and images may be helpful. Combinations of thinning and surface fuel treatments can be examined in the guide to evaluate their effects on forest stand structure and potential fire behavior.
- Step 2. If other kinds of treatments are preferred, or if stand data are available, FFE-FVS could be used to generate customized simulations of the effects of thinning and surface fuel treatments. Specify tree regeneration following thinning to reflect local conditions.
- Step 3. The Understory Response Model could be used to determine how thinning and surface fuel treatments such as prescribed burning would affect key forage species for deer and elk.
- Step 4. The Wildlife Habitat Response Model may be used to determine stand structure and vegetation characteristics that would benefit deer and elk populations.
- Step 5. If prescribed burning is included in an alternative, consider using FOFEM to calculate fuel consumption and emissions. Although this information is not central to the objectives of the project, it will be needed to quantify environmental effects.
- Step 6. My Fuel Treatment Planner can be used to calculate the economic costs and benefits associated with conducting alternative treatments.

Example 2–Small to Moderate Watersheds

(Approximately 5th- to 6th-field HUC watershed)

The Deschutes National Forest wants to develop a strategy to reduce crown fire hazard and suppression costs related to protection of the wildland-urban interface in a key watershed near Bend, Oregon. This area is currently dominated by a mixture of young stands of ponderosa pine and stands of large ponderosa pine canopy with dense Douglas-fir and white fir subcanopy. Additional objectives include generating economic opportunities for the local community while minimizing smoke production.

- Step 1. Obtain relevant geospatial layers for display in a GIS. These layers can include forest stand structure, stand age, fuels, and cover type. If adequate stand inventory data are available, the Landscape Management System (LMS) can be used to display three-dimensional structure across landscapes up to 50,000 acres (see http://lms.cfr.washington.edu).

- Step 2. The FCCS could be used to classify and quantify fuelbeds across the landscape. This requires some decisions about how many fuelbeds are adequate to characterize the variability. Each FCCS fuelbed will contain detailed fuel data and fire potentials.
- Step 3. Consider using SIMPPLLE to generate probability maps of disturbance processes and vegetation attributes. These maps can be used to assign priorities for fuel treatments based on spatial patterns of fuels across large landscapes. Changes in the occurrence and intensity of wildfire and other disturbance processes can be evaluated with alternative fuel treatments that vary in space and time. Priorities and planning can be based on potential fire spread as well as other factors such as forest structure and wildlife habitat.
- Step 4. The SIS can be used to calculate potential emissions from smoke generated by fuel treatments that include prescribed burning. This may include broadcast burning as well as pile burning. It is especially important to evaluate PM2.5 production with respect to potential effects on health in areas where people live. Fuel treatment alternatives that minimize smoke production can then be identified.
- Step 5. My Fuel Treatment Planner can be used to calculate net present value of alternative fuel treatments. This analysis requires only "cut lists" for thinning treatments, and all other outputs can be calculated directly from user inputs. Economic status must be calculated stand by stand, and can be aggregated over space and time to determine overall financial costs and benefits, including potential to sustain local employment.

Example 3–Large Watershed to National Forest

(Approximately 4th-field HUC)

The Colville National Forest wants to develop a large-scale strategy for integrating fuel management with desired conditions for vegetation structure and air quality. This strategy will include the entire Colville National Forest and reservation lands managed by the Colville Federated Tribes.

- Step 1. Obtain relevant geospatial layers for display in a GIS. These layers can include forest stand structure, stand age, fuels, and cover type.
- Step 2. The FCCS can be used to classify and quantify fuelbeds across the landscape. This requires some decisions about how many fuelbeds are

adequate to characterize the variability and at what spatial scale fuel can be classified. Each FCCS fuelbed will contain detailed fuel data and fire potentials.

- Step 3. Consider using the Fireshed process to focus on the effects of alternative fuel treatment strategies on fire regime, fire hazard, and potential wildland fire behavior. Fireshed can facilitate delineation of landscape management and assessment, and strategies that attain desired conditions for fire behavior, forest health, and habitat. FARSITE can be used to test the potential effects of different fuel treatments on fire behavior across landscapes subjected to a fire or group of fires. FlamMap creates raster maps of potential fire behavior characteristics (rate of spread, flame length, crown fire activity) and environmental conditions (dead fuel moistures, midflame windspeeds) over an entire FARSITE landscape.
- Step 4. The VDDT can be used to examine changes in vegetation and fuel conditions given different management scenarios, disturbance regimes, and fuel treatments. Results are not spatial, so spatial strategies for fuel treatments cannot be examined. However, the model is useful for estimating vegetation, fuel, and fire trends given different combinations and timing of fuel treatments. The VDDT outputs can be compared and combined with FARSITE outputs to obtain a broader perspective on the effects of alternative fuel treatments.
- Step 5. The Consume and FEPS components of BlueSky can be used to calculate PM2.5 concentrations from potential prescribed burns and wildfires in the landscape being managed, and to display smoke trajectories from burn locations. Outputs can be overlain on GIS layers such as topography, roads, hospitals, schools, and Class I wilderness. This information will assist the development of spatial patterns of fuel treatment that minimize smoke production over space and time. It will also indicate potential tradeoffs in smoke production from wildfires versus prescribed fires.

Species Mentioned

Common name	**Scientific name**
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Lodgepole pine	*Pinus contorta* Dougl. ex Loud.
Ponderosa pine	*Pinus ponderosa* Dougl. ex Loud.
White fir	*Abies concolor* (Gord. Glend.) Lindl. ex Hildebr.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.54	Centimeters
Inches	25,400	Microns
Feet	0.3048	Meters
Miles	1.609	Kilometers
Square miles	2.59	Square kilometers
Acres	0.405	Hectares
Degrees Fahrenheit	(F-32)/1.8	Degrees Celsius

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Appendix 1: Tools

For list of acronyms and models, see appendix 2.

Armillaria Response Tool (ART) (Root Disease Analyzer)

Application for fuel treatment	ART can help reveal timber stands with site conditions that indicate risk for developing *Armillaria* root disease, if susceptible host trees are present. It is intended to help users (e.g., fuel treatment planners, silviculturists, resource managers, and NEPA planners) make predictions and evaluate potential impacts of fuel treatments.
Description	ART is a Web-based tool that can estimate *Armillaria* root disease risk in dry forests of the Western United States. It uses habitat types to identify sites with high or low risk potential for developing *Armillaria* root disease, and indicates how some fuel management activities may exacerbate *Armillaria* disease in high-risk stands. ART also helps determine an appropriate fuel management plan for reducing future damage by *Armillaria* root disease.
Appropriate spatial scale	One to several stands, but can be aggregated to larger scales.
Analyst requirement	The user must be familiar with habitat typing within the region of the stand location. Accurate identification of habitat type is critical.
Data inputs	Inputs for the stand-level tool include: √ Stand location: Choices of stand location are currently limited to forested areas in the intermountain West (Idaho, Oregon, Washington, Montana, Utah, and Wyoming). √ Habitat type: Associations of plant species, known as habitat types, are strong indicators of site conditions as influenced by the interaction of topography, soils, temperature, and precipitation patterns. Lists of habitat types are taken from the 12 habitat type manuals that cover the Rocky Mountain Montane Conifer Forest biotic communities.

√ Fuel treatment: Fuel treatments include (1) no treatment, (2) thinning, (3) prescribed burning, and (4) wildfire.

Outputs

Outputs of the tool suggest whether a stand has high or low risk of pathogenic *A. ostoyae* being present and the potential effects of different fuel treatments on *Armillaria* root disease. Outputs for ART include:

√ Subseries: Subseries categories comprise groups of habitat types that reflect combined temperature-moisture regimes.

√ Fire group: Indicates a cluster of habitat types based on response of dominant tree species to fire, potential frequency of fire, and similarity in postfire succession. Fire groups are not available for every region described in the tool.

√ Fire regime: Fire behavior in Western forests has been classified into five fire regimes based on moisture and temperature gradients determined by subseries. Fire regimes are separated into broader categories than fire groups and are available for every region.

√ *ARMILLARIA* regime: Likelihood of *Armillaria* impact on a stand (low or high) that depends on the subseries of the stand and the seral and climax tree species found on the site.

√ Potential impact on conifer species by subseries: List of potential impacts of *Armillaria* disease is presented based on presence and successional role of conifer species.

√ Likely impact of fuel treatment on *Armillaria* root disease: Fuel treatments under consideration include (1) no treatment, (2) thinning, (3) prescribed burning, and (4) wildfire. A proposed synopsis is provided on the potential activity of *Armillaria* after a fuel treatment. Within subseries where pathogenic *A. ostoyae* does not occur, fuel treatments will not affect *Armillaria* root disease, regardless of host tree species present. Within subseries where pathogenic *A. ostoyae*

	does occur, fuel treatments may affect *Armillaria* root disease.
Linkage to other models/tools	No direct links to other programs are presently available. However, ART can be used in conjunction with other models developed by the Fuels Planning: Science Synthesis and Integration Project, to estimate other potential effects of fuel treatments on stands.
Developers (partners)	USDA Forest Service—Fuels Planning: Science Synthesis and Integration Project, and the Rocky Mountain Research Station.
Current status	Available for use at small scabes. Broader scale version is in development. Additional information is available at http://forest.moscowfsl. wsu.edu/fuels.
Training availability	May be arranged on request from contacts listed below.
Technical documentation	Documentation is available at http://forest.moscowfsl. wsu.edu/fuels/art/.
Contact	Tom Rice USDA Forest Service trice@fs.fed.us or Mee-Sook Kim USDA Forest Service mkim@fs.fed.us
Additional information	Root rot caused by *Armillaria* fungi warrants special consideration before fuel management activities are selected in Western forests. *Armillaria* species are widely distributed, and their effects on disease and mortality can increase greatly after human-caused disturbances. In many environments, pathogenic *Armillaria* fungi cause reduced tree growth, increased mortality, and predisposition to bark beetle attack. In addition, *Armillaria* root disease can increase wildfire risk by contributing to fuel accumulation and fuel ladders.

BehavePlus

Application for fuel treatment	In fuels projects, BehavePlus can be used to predict surface fire flame length, rate of spread, tree mortality, crown scorch height, spotting distance, and fire containment.
Description	The BehavePlus fire modeling system is a Microsoft Windows[1] application to predict wildland fire behavior for fire management purposes. It is designed for use by fire and land managers who are familiar with fuels, weather, topography, wildfire situations, and associated terminology.
Appropriate spatial scale	Primarily stand scale but can be used to assess 6th-field hydrologic unit codes (HUCs).
Analyst requirement	Requires a basic understanding of fire behavior inputs and outputs. The tool is not data intensive, but the user needs to be familiar with the differences in fuel models and underlying assumptions of the mathematics in the model to provide accurate inputs and to interpret outputs.
Data inputs	Inputs differ with modules used. Typical modules used for fuel planning include SURFACE, CROWN, CONTAIN, SPOT, SCORCH, and MORTALITY. Users can run each module separately or link the runs through SURFACE. √ SURFACE inputs—Fuel model, live and dead fuel moistures, windspeed (midflame or 20-foot with adjustment factor), direction for which to calculate maximum rate of spread or upslope direction of spread, wind direction (upslope or degrees clockwise from either upslope or north), and slope steepness. √ CROWN inputs—The same inputs as SURFACE plus canopy base height, canopy bulk density, and foliar moisture.

[1] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

√ CONTAIN inputs—Maximum rate of spread, fire size at report, length-to-width ratio of the fire, suppression tactic, line construction offset, resource name, resource line production rate, resource arrival time, and resource duration.

√ SPOT inputs (for torching trees)—Mean cover height, tree height, spotting tree species, diameter at breast height, 20-foot windspeed, ridge-to-valley elevation difference, ridge-to-valley horizontal distance, spotting source location (valley bottom, midslope, ridgetop, lee side of ridge, windward side of ridge), and number of torching trees.

√ SCORCH inputs—Midflame windspeed, air temperature, and flame length.

√ MORTALITY inputs—Tree height, crown ratio, mortality tree species, bark thickness, scorch height.

Outputs

Users can specify the types of outputs provided in modules with more than one output option. For fuel planning, the most common outputs used include the following.

√ SURFACE outputs—Rate of spread, flame length, direction of maximum spread if not uphill, midflame windspeed if 20-foot windspeed used, wind/slope/spread direction diagram if direction of maximum spread is not uphill, and fire characteristics chart. The fire characteristics chart provides a graph of heat per unit area versus rate of spread with flame length categories, allowing users to note when fire behavior is expected to exceed the limitations of hand crews, mechanical equipment, and erratic fire behavior.

√ CROWN outputs—Critical surface fire intensity, critical surface fire flame length, transition ratio, whether the fire will transition to crown fire, crown rate of spread, critical crown rate of spread, active ratio, whether the fire will be an active crown fire, fire type, and crown spread distance (if a time is specified in the inputs).

	√ CONTAIN outputs—Containment status (contained or escaped), contained area, fireline constructed, number of resources used, and containment diagram. The containment diagram displays the fireline constructed relative to the fire length-to-width ratio along with other output data related to the fire. √ SPOT output—Spotting distance from torching trees. √ SCORCH output—Scorch height. √ MORTALITY outputs—Bark thickness, tree crown length scorched, tree crown volume scorched, and probability of mortality.
Linkage to other models/tools	There are no direct linkages to other tools, but the √ BehavePlus equations are the basic underlying equations used in FOFEM, FMA Plus, FFE-FVS, NEXUS, FARSITE, and FlamMap.
Developers (partners)	Forest Service Rocky Mountain Research Station (Systems for Environmental Management).
Current status	BehavePlus 3.0.1 is fully functional and includes the new fuel models released in spring 2005. Additional information is available at http://www.fire.org. Future versions are expected to add table shading for use in prescribed fire planning, postfrontal combustion, and soil heating, potentially resulting in a merging of FOFEM and BehavePlus.
Training availability	Self-directed tutorial available at Web site where the program files can be downloaded, http://www.fire.org. S-390 Intermediate Wildland Fire Behavior class provides students with training on use of SURFACE, CONTAIN, and SPOT. Concepts useful for the SCORCH and MORTALITY modules in BehavePlus can be obtained from RX-310 Introduction to Fire Effects class.
Technical documentation	Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment

Station. 40 p. Surface fire spread model that is a fundamental component of BehavePlus.

Anderson, H.E. 1982. Aids to determining fuel models for estimating fire behavior. Gen. Tech. Rep. INT-122. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 22 p. http://www.fs.fed.us/rm/pubs_int/int_gtr 122.html. Describes the 13 standard fire behavior fuel models. Pictures of the fuel models are included in the BehavePlus program.

Andrews, P.L.; Bevins, C.D.; Seli, R.C. 2005. BehavePlus fire modeling system, version 3.0: User's guide. Gen. Tech. Rep. RMRS-GTR-106WWW. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 142 p. http://www.fs.fed.us/rm/pubs/rmrs_gtr106.html.

Contact

Fire and Aviation Management Helpdesk
USDA Forest Service
1-800-253-5559
fire_help@dms.nwcg.gov
http://fire.org/index.php?option=content&task=category&sectionid=2&id=7&Itemid=26

Additional information

BehavePlus can be used to provide basic analyses of potential fire behavior before and after fuel treatments. The original 13 fuel models are considered too coarse to display some of the differences in potential fire behavior that can be present both before and after fuel treatments. Potential fire behavior in many fuel types is not well represented in the original models. The recent addition of 42 fuel models partially addresses this problem.

BehavePlus can assess potential spotting distance and how initial attack success is likely to change after those fuel treatments designed to increase suppression effectiveness. Some aspects of suppression effectiveness are qualitative.

BehavePlus can be used to assess potential fire behavior at large spatial scales when data are insufficient to support the use of other tools, such as FlamMap. In those cases, estimates can be made for each stand for key fire behavior elements, classes of behavior identified (i.e., low, moderate, high, and extreme rates of spread), and maps prepared by using stands as the basic unit. This approach requires modifying certain stand features such as slope steepness, exposure to wind, fuel moisture, and weather inputs.

BehavePlus ties crowning potential to flame length, but other support tools such as FlamMap, FMA Plus, and NEXUS, use a variety of approaches to assess crown fire potential. The output provided by BehavePlus, FlamMap, FMA Plus, and NEXUS may well differ.

BlueSky Smoke Forecast System (BlueSky)

Application for fuel treatment	Help land managers meet prescribed burn goals by providing a forecast of where surface smoke from burning operations could go, in order to mitigate potential negative impacts to sensitive receptors and to aid in go/no-go decisions.
Description	A framework of models linking burn information, meteorology, mapped fuel loadings, fuel consumption and emission models, and dispersion and trajectory models, to yield a forecast of surface smoke concentrations from prescribed fire and wildfire across a region.
Appropriate spatial scale	Applicable on a regional or national scale, where the scale is determined by the meteorology forecast domain and the availability of mapped fuel loadings. BlueSky is currently being run for the following domains and scales: √ Washington, Oregon, Idaho, western Montana–4-km resolution √ Washington, Oregon, Idaho, western Montana, northern California, northern Nevada, southwest Canada–12-km resolution √ Western United States–36-km resolution √ Rocky Mountain region–6-km resolution
Analyst requirement	Readily accessible at http://www.blueskyrains.org, but data are best viewed or interpreted by someone with knowledge of smoke dispersion, meteorology, and fire.
Data inputs	Burn information—Currently BlueSky is integrated with the FASTRACS[2] system used by the Forest Service and Bureau of Land Management to manage prescribed burning in Oregon; the Washington State Department of Natural Resources SMOKEM prescribed burning system; the Montana-Idaho Airshed Group's RAZU

[2] Fuel Analysis, Smoke Tracking, and Report Access Computer System. http://www.fs.fed.us/r6/fire/fastracs/

burn reporting system[3] (which accounts for most federal, state, and private burning in the two states); and the wildfire 209 incident status summary, which contains a daily record of wildfires occurring nationally.

√ Meteorology—A three-dimensional description of a windfield and other meteorological parameters is necessary to drive the trajectory and dispersion models in BlueSky. Currently BlueSky is integrated with MM5 output products from the University of Washington, University of California-Santa Barbara, and the Rocky Mountain FCAMMS Consortium MM5 forecast system.

√ Fuel loadings—BlueSky offers a selection of fuel load mappings. There is a 1-km-resolution (0.62-mile) fuel load coverage for the Western United States. BlueSky is also using the 1-km National Fire Danger Rating System (NFDRS) fuel load mapping. Work is underway to use FCCS fuel load mapping.

Outputs

√ Predicted PM2.5 concentrations from planned prescribed burns and ongoing wildfires

√ Trajectories from each burn location showing where neutrally buoyant smoke will travel (horizontally and vertically) over the next 12 hours

√ Trajectories from default locations across the domain that are used to indicate where smoke from a burn would go if a burn were lit at that location. This tool is useful in cases for which a burn did not get into BlueSky.

These outputs are displayed in the Rapid Access Information System (RAINS) developed by partners at Environmental Protection Agency (EPA). RAINS is a Web-based geographic information system (GIS) application that allows for overlay of BlueSky outputs on GIS layers such as topography, census information, roads, hospitals, schools, and Class I wilderness.

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[3] http://www.fs.fed.us/r1/fire/nrcc/Smoke_web_pages/razu_ug.pdf

Linkage to other models/tools	BlueSky links many pieces of existing data and models, including the Fire Emission Production Simulator (FEPS), Consume, FCCS, NFDRS, CALPUFF, MM5, HYSPLIT, FASTRACS, MT/ID Airshed Group, and Washington Department of Natural Resources and ICS-209 wildfire incident status summary reports.
Developers (partners)	Forest Service Pacific Northwest Research Station; Bureau of Land Management; National Park Service; U.S. EPA Region 10; University of Washington; Washington State University; Washington State Department of Ecology; Idaho Department of Environmental Quality; Oregon Department of Forestry; Montana-Idaho Airshed Group; Montana Department of Environmental Quality; Nez Perce Tribe; Coeur d'Alene Tribe.
Current status	Fully functional. Available at http://www.blueskyrains.org.
Training availability	Annual training workshops are taught by Jeanne Hoadley (jhoadley@fs.fed.us), USDA Forest Service Pacific Northwest Research Station
Technical documentation	http://www.fs.fed.us/bluesky/
Contact	Narasimhan Larkin USDA Forest Service (206)732-7849 larkin@fs.fed.us
Additional information	None.

Comparative Risk Assessment in Fire and Fuels Planning (CRAFT)

Application for fuel treatment	Calculates the relative risks and tradeoffs associated with alternative fire and fuel management scenarios. Identifies which variables and assumptions have the greatest influence.
Description	CRAFT is a Web-based tool that leads natural resource managers through an integrated assessment of risks, uncertainties, and tradeoffs that surround fire and fuel management. CRAFT helps planners identify and clarify objectives, design alternatives, assess probable effects, and compare and communicate risks. It integrates data, model outputs, and personal beliefs. CRAFT helps planners design alternatives based on how well they might satisfy objectives. Relatively crude models are developed in the "Alternative Design" section, paving the way for a more detailed analysis of tradeoffs in the "Effects" section that follows. Designing alternatives is iterative. CRAFT users alter, add, or remove alternatives from consideration based on initial analysis of alternative effects. Analyzing effects probabilistically helps planners readily see the most important components of projects. This helps managers revise alternatives to better meet objectives.
Appropriate spatial scale	Best for large scale (e.g., 4^{th}-field HUC) but can be applied at smaller scales.
Analyst requirement	Appropriate for use by experienced or relatively inexperienced planning teams, but it helps to have expertise in decisionmaking with multiple options and outcomes.
Data inputs	Objectives of management action.
Outputs	Probabilistic estimates of outcomes for various treatment options on a landscape, including vegetation, fire characteristics, and suppression costs.

Linkage to other models/tools	Can work with BehavePlus, FVS, and FARSITE.
Developers (partners)	Pacific Southwest Research Station; School of Business, University of Wisconsin-Milwaukee
Current status	CRAFT is an ongoing project. For more information and to check on the availability and specific capabilities of CRAFT with respect to your project, see "Contact."
Training availability	Web site at http://www.fs.fed.us/psw/topics/fire_science/craft/craft.
Technical documentation	Lee, D.C.; Irwin, L.L. 2005. Assessing risks to spotted owls from forest thinning in fire-adapted forests of the Western United States. Forest Ecology and Management. 211: 191-209.
Contact	Dr. Steven P. Norman USDA Forest Service (707) 825-2919 stevenorman@fs.fed.us
Additional information	Belief nets allow decisionmakers to explore the relative effects of different choices on intermediate variables and final outcomes. One can also determine which actions, variables, or events most affect specific resources of interest. If the risks seem too high under all alternatives, belief nets help identify where additional knowledge may help decrease uncertainties resulting from lack of information. CRAFT provides a framework to improve communication among all stakeholders by transparently portraying objectives, tradeoffs, uncertainties, and risk tolerance. Uncertainty is unavoidable in all decisions, but different uncertainties have different consequences. The use of probability in CRAFT portrays relative uncertainties and their relevance to each stakeholder group.

Consume 3.0

Application for fuel treatment	Consume predicts fuel consumption and pollutant emissions from wildland fires. Resource managers can use Consume to plan treatment windows that satisfy fuel reduction goals while minimizing pollutant emissions. Consume will also provide fuel consumption and emissions information for dispersion models and for national and regional fuel consumption, emissions, and carbon assessments and inventories.
Description	Consume is designed for resource managers, fire managers, researchers, air quality regulators, and carbon modelers with some working knowledge of Microsoft Windows applications. The software predicts the amount of fuel consumption and emissions during wildland fires in all fuelbed types based on fuel loadings, weather conditions, site environmental data, and fuel moisture. Using these predictions, resource managers can determine when and where to conduct a prescribed burn (or manage a wildland fire) to achieve desired objectives while reducing impacts on other resources and for smoke reporting. Consume can be applied to most forest, shrub, and grassland systems in North America.
Appropriate spatial scale	Consume can be used at any spatial scale, from a single fuelbed in a burn unit to national assessments. It is most commonly applied to burn units confined to a single project area, e.g., within a watershed or small subset of a national forest district or BLM resource area.
Analyst requirement	Anyone who is comfortable using Microsoft Windows applications will be able to easily navigate the Consume user interface. However, a working knowledge of fuels and prescribed fire prescriptions is still required to obtain reliable model results.
Data inputs	Consume contains a library of files for FCCS fuel loadings. Fuels are organized into six strata: canopy, shrub,

nonwoody vegetation, downed woody fuels, a litter-lichen-moss layer, and ground fuels. Each stratum is further broken down into one or more fuelbed categories. Users can select a fuel loadings file based on selection criteria (e.g., ecoregion, vegetation form, cover type or change agent) or the FCCS fuelbed identification number. Alternatively, users can enter their own fuel data directly into Consume. Additional inputs include information about the project, burn unit, type of fire, weather conditions, and environmental data such as fuel moistures, midflame windspeed, slope, and whether the fuelbed was created through natural processes or timber harvest activities.

Outputs	Consume calculates fuel consumption and emissions by combustion phase for each fuelbed stratum and category based on input fuel loadings and environmental conditions. Users can specify a variety of report options, including consumption or emissions by date, fire combustion phase, and range of 1,000-hour fuel moistures. Consumption and emissions by 1,000-hour fuel moistures also can be viewed graphically to visually determine favorable burn conditions. Fuel consumption and fire emissions may be reported at multiple spatial scales, including projects, units, fuelbeds, and fuel strata. Users also may use a scenario-testing tool to model prescribed burns under a variety of environmental conditions to determine favorable burning conditions. Results can be printed directly in Consume or exported into spreadsheets, databases, or statistical packages for additional analysis.
Linkage to other models/tools	Consume contains a library of fuel loading files exported from FCCS and an update option to remain current with future versions of FCCS. Consume can be run in batch mode to support linkages with BlueSky, SmokeTracs, and other applications on operating systems that do not support the Microsoft Windows-based user interface.

Developers (partners)	Forest Service Pacific Northwest Research Station (Hoefler Consulting Group, Seattle, Washington; University of Washington; Forest Service Rocky Mountain Research Station)
Current status	Consume v. 3.0 was released in 2005. Available at http://www.fs.fed.us/pnw/fera/products/consume.html.
Training availability	A tutorial is available at http://www.fs.fed.us/pnw/fera/products/consume.html.
Technical documentation	Prichard, S.J.; Ottmar, R.D.; Anderson, G.K. [In preparation]. Consume 3.0 User's Guide. http://www.fs.fed.us/pnw/fera/consume/consume30_users_guide.pdf.
Contact	Roger Ottmar USDA Forest Service (206)732-7826 rottmar@fs.fed.us
Additional information	See http://www.fs.fed.us/pnw/fera/products/consume.html.

Fire Area Spread Simulator (FARSITE 4.0.4)

Application for fuel treatment	FARSITE can be used to test the potential effects of different fuel treatments on landscapes subjected to a fire or group of fires burning under a given weather stream.
Description	FARSITE is a fire growth simulation model that uses spatial information on topography and fuels along with weather and wind files. It incorporates the existing models for surface fire, crown fire, spotting, and fire acceleration into a two-dimensional fire growth model.
Appropriate spatial scale	Small watersheds (e.g., 6th-field HUC) to large landscapes (4th-field to 5th-field HUC).
Analyst requirement	FARSITE requires a high level of expertise for the analyst and for GIS support. Users can teach themselves to run FARSITE, but considerable experience is needed to competently run simulations and judge how realistic outputs are. Creating the necessary data layers to support FARSITE requires a relatively high level of GIS expertise. Most data layers are created through remote sensing to provide wall-to-wall coverage at the same resolution. The usefulness of both tools increases greatly when the data layers include inholdings and adjacent lands.
Data inputs	FARSITE uses up to eight base data layers of which five are mandatory and three are optional. These layers must be in raster format and are combined to create a landscape file. √ The five mandatory layers are slope, aspect, elevation, canopy cover, fuel model. √ The three optional layers are canopy base height, canopy ceiling height, canopy bulk density. These layers are needed to include spotting from torching trees and crown fire simulation. In the absence of these three layers, the models assume fully stocked stands of fully crowned Douglas-fir.

	FARSITE allows importing of auxiliary grid and vector files for features such as roads, streams, barriers, point locations, etc. It requires weather and wind files, which can be extensive and should overlap the analysis period by at least 24 hours on each side. A large number of run parameters must be specified, such as time step to be used in calculations, visible steps to display, perimeter resolution, and distance resolution. Crown fire can be enabled or disabled. Spotting can be enabled or disabled, and include or exclude torching trees and a specified ignition frequency. FARSITE requires a fire start location.
Outputs	FARSITE produces maps of fire behavior parameters in exportable form, and graphs and tables of fire area, perimeter, fire characteristics chart plots, postfrontal combustion, wind gauge locations, and weather station locations.
Linkage to other models/tools	FlamMap uses FARSITE landscape files. Current development efforts include a large-scale fuel treatment optimization model that uses features from both FARSITE and FlamMap.
Developers (partners)	U.S. Department of Agriculture, Forest Service Rocky Mountain Research Station (Bureau of Land Management, National Park Service, Bureau of Indian Affairs, Systems for Environmental Management)
Current status	FARSITE 4.1.03 is fully functional. For more information, see http://www.fire.org.
Training availability	FARSITE use is taught in S-493 Fire Area Simulation, and the program includes a tutorial in the help files.
Technical documentation	Finney, M.A. 1998. FARSITE: Fire Area Simulator—model development and evaluation. Res. Pap. RMRS-RP-4, Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p. Finney, M.A. 1999. Spatial modeling of post-frontal fire behavior. Final Report RMRS-99557-RJVA. Missoula, MT: Systems for Environmental Management. 8 p.

	Keane, R.E.; Mincemoyer, S.A.; Schmidt, K.M.; Long, D.G.; Garner, J.L. 2000. Mapping vegetation and fuels for fire management on the Gila National Forest Complex, New Mexico. Gen. Tech. Rep. RMRS-GTR-46-CD. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p. [plus CD-ROM].
Contact	National Interagency Fire Center Computer Support Desk (800) 253-5559 fire_help@dms.nwcg.gov
Additional information	FARSITE is intended to simulate fire spread for a single start or group of starts using a weather stream for the days to be assessed. FARSITE is most accurate when calibrated by using previous weather data and fire perimeters for a particular fire. The model will run simulations for any time desired, but cumulative errors make outputs after 5 simulation-days unreliable. When spotting is enabled, several simulations should be run using the same weather streams and model parameters, because spotting is stochastic, and each run will produce different results. FARSITE output files can be imported into GIS and analyzed further or displayed with different layers stored in polygon format.

Fire Behavior Assessment Tool (FBAT)

Application for fuel treatment	Designing and prioritizing hazardous fuel treatments, and evaluating the effectiveness of proposed treatments in altering potential fire behavior.
Description	The Fire Behavior Assessment Tool provides an interface between the ArcMap geographic information system (GIS) and FlamMap3, a fire behavior mapping and analysis program that calculates potential fire behavior characteristics at a stand level. Users may select any threshold of flame length, rate of spread, and crown fire activity. They may choose to map a single metric fire behavior (Absolute Fire Behavior Query), maps of each threshold including only those polygons exceeding the threshold (Simple Query), or maps of each threshold where polygons are classified based in multiple degrees (Classification Query) such as low, medium, and high.
Appropriate spatial scale	Small
Analyst requirement	Low
Data inputs	√ LANDFIRE topography, surface fuel, and canopy fuel GIS data layers. √ Historical weather records. √ Threshold limits for flame lengths, rate of spread, and crown fire activity (required only for Simple Query and Classification Query).
Outputs	√ Potential flame length GIS data layer(s). √ Rate of spread GIS data layer(s). √ Crown fire activity GIS data layer(s).
Linkage to other models/tools	LANDFIRE (provides data layers). FlamMap3 (calculates fire behavior).
Developers (partners)	National Interagency Fuels Technology Team.
Current status	FBAT is currently undergoing beta testing.
Training availability	Informal.
Technical documentation	Not yet available.

Contact	Jeffrey L. Jones USDA Forest Service (406) 758-5341 jjones@fs.fed.us
Additional information	The Fire Behavior Assessment tool provides an interface between FlamMap and ArcMap that allows users to run FlamMap from the ArcMap platform. FBAT converts ArcGRIDS depicting topography and fuels characteristics into ASCII files, builds the landscape profile, and initiates a FlamMap run. FBAT then converts the FlamMap outputs from ASCII format to ArcGRID format for display and to facilitate additional analysis. FBAT contains a user interface that can be used to query the three spatial layers derived by FlamMap. Caution is urged in interpreting the single metric derived from the integration of the three layers; it is recommended that users simply use these metrics to evaluate relative differences of potential fire behavior and avoid any interpretation pertaining to the absolute consequences of a specific wildland fire event.

Fire Ecology Assessment Tool (FEAT)

Application for fuel treatment	Application for storing, managing, and analyzing National Park Service (NPS) fire effects monitoring data
Description	FEAT is a comprehensive, relational database management system that was developed to support immediate and long-term monitoring and reporting of fire effects in the National Park Service units. The system will make monitoring data readily available at the park level, with the long-term goal of having Internet-accessible databases at the local, regional, and national levels in order to disseminate results to land managers (fire and resource professionals) and other scientists. FEAT's data structure and design will facilitate data sharing between the NPS Wildland Fire Management Program, natural resource programs, and other agencies, resulting in broader and more comprehensive landscape-scale assessments. FEAT is an integrated tabular and spatial information system supporting data management and analysis for immediate and long-term monitoring and reporting of fire effects. FEAT is based on the integration of ArcView (9.0) and Microsoft Desktop Engine. FEAT is designed to use PDAs (personal data assistants) for field data collection and automated database updating. FEAT also includes an interactive "Protocol Builder" that supports automatic updating of new protocol database tables and data collection screens.
Appropriate spatial scale	Local to regional
Analyst requirement	Low
Data inputs	√ Brush or grass burn severity data recorded for a planned or unplanned disturbance event when the disturbance type is fire.

√ The fire behavior data recorded for a planned or unplanned disturbance event when the disturbance type is fire.

√ Tree burn severity data recorded for a planned disturbance event when the disturbance type is fire.

√ Weather data recorded for a planned or unplanned disturbance event when the disturbance type is fire.

√ The date, time, location, and protocol for collecting sampling data related to a disturbance.

√ The spatial dimension of a disturbance.

√ The diameter and condition of 1,000-hour fuel along a transect within a plot.

√ The depth of litter and duff along a transect within a plot.

√ The number of 1-hour, 10-hour and 100-hour fuels along a transect within a plot.

√ The date, time, location, and protocol for collecting sampling data related to a type of monitoring: vegetation, fuels, or disturbance.

√ The species code, live/dead flag, and tally for herbs found within a frame.

√ The species code, live/dead flag, and height for herbs found along a transect.

√ The user identification of the individual who recorded measurement data.

√ The species code, age, and tally for shrubs within a belt transect.

√ The species code, d.b.h. (diameter at breast height), damage code, and live/dead flag for trees within a plot.

√ The species code, height, resprout flag code, live/dead flag, and tally for trees within a plot.

√ The unique identification of a major fuel-vegetation complex or vegetation association subject to a particular treatment prescription.

√ The management objectives selected for a monitoring type.

	√ The spatial dimension of the monitoring type. √ A National Park Service code to designate a national park. √ A landscape unit used to collect sampling data. √ A line with beginning and end points within a plot used to collect species data. √ A visit to a plot and the associated visit code that identifies the reason for the visit. √ The catalog of approved sampling methods used to collect monitoring data. √ The spatial dimension of the treatment. √ The management objectives associated with a monitoring type. √ The protocols selected for a monitoring type.
Outputs	√ Generates summary statistics for fuels. √ Summaries of input data with user-defined classifications to review fire effects data.
Linkage to other models/tools	Replaces the NPS fire monitoring handbook, which is no longer supported.
Developers (partners)	National Park Service (Spatial Dynamics)
Current status	FEAT version 2.4
Training availability	Informal.
Technical documentation	User's Guide: http://feathelp.spatialdynamics.com Spatial User's Guide: http://featgishelp.spatialdynamics.com
Contacts	A forum is available at http://forum.spatialdynamics.com
Additional information	An effort is currently underway to merge FEAT and FIREMON into a single system that includes spatial links (currently lacking in FIREMON) and statistical analysis (currently lacking in FEAT).

Fire Effects Information System (FEIS)

Application for fuel treatment	Provides background information on the potential effects of fire on flora and fauna.
Description	FEIS summarizes and synthesizes research about living organisms in the United States—their biology, ecology, and relationship to fire. It is based on literature reviews, taken from current English-language literature of almost 900 plant species, about 100 animal species, and 16 Küchler plant communities found on the North American continent. The emphasis of each review is fire and how it affects each species. Background information on taxonomy, distribution, basic biology, and ecology of each species is also included. Reviews are thoroughly documented, and each contains a complete bibliography.
Appropriate spatial scale	Can be applied at any spatial scale
Analyst requirement	No specialized skill required.
Data inputs	None
Outputs	Bibliographic information
Linkage to other models/tools	None
Developers (partners)	USDA Forest Service, Rocky Mountain Research Station
Current status	Available online at http://www.fs.fed.us/database/feis.
Training availability	Tutorial available at http://www.fs.fed.us/database/feis/tutorial/scavenger_hunt.html.
Technical documentation	Research project summaries available http://www.fs.fed.us/database/feis/research_project_summaries/index.html.

Contacts	Cam Johnston (406) 329-4810 cjohnston@fs.fed.us or Jane Kapler Smith (406) 329-4805 jsmith09@fs.fed.us
Additional information	FEIS is currently undergoing extensive updating of older species accounts and some redesign of the information reported.

Fire Effects Planning Framework (FEPF)

Application for fuel treatment	Creates map libraries useful for identifying where, and under what burning conditions, fire may be beneficial for achieving fuel treatments with respect to fire behavior and effect upon other management objectives. Areas where fire is likely to result in detrimental effects may be candidates for mechanical treatments or fire under less severe conditions.
Description	FEPF simultaneously calculates risks and benefits from fire under a variety of fire weather conditions. FEPF is an analytic framework that steps the user through a series of existing software programs to generate spatially explicit map libraries depicting the effect of fire on resources of interest.
Appropriate spatial scale	FEPF can be used at any scale from stand to landscape. Appropriate scale of analysis depends on the accuracy of underlying data used, but in any case is not less than the 30-meter (100-foot) scale of vegetation and fuel data inputs.
Analyst requirement	Local expertise is required to develop the crosswalk among mapable entities (such as vegetation type and structure), management objectives, and fire behavior and fire effects on management objectives. A landscape dynamic simulation model is required if users wish to consider future scenarios. Subject matter experts need to be consulted to specify fire weather parameters, wildlife-habitat relationships, and fire effects on key habitat characteristics.
Data inputs	FEPF requires information on fire behavior, vegetative conditions, and fire effects on management objectives. At its most basic, FEPF requires users to model fire behavior under a series of locally derived fire weather conditions (typical of moderate, severe, and extreme fire weather conditions).

This is generally obtained from an analysis of historical weather conditions that uses FireFamilyPlus, followed by FlamMap runs for each of the fire weather scenarios (although users could use FFE-FVS in combination with a landscape interpolation program, instead of FlamMap). FlamMap requires:

√ Slope	√ Fuel model
√ Aspect	√ Stand height
√ Elevation	√ Crown base height
√ Canopy cover	√ Canopy bulk density

Alternatively, analysts can use vegetation dynamics simulators (such as SIMPPLLE) to generate qualitative fire behavior measures. Management objectives must be mapped; generally this requires tying key habitat or species characteristics to geospatial vegetative attributes. Information about fire effects on management objectives may be obtained from a variety of sources, including fire effects information system, other software (such as the WHRM or URM), published literature, and local expertise.

Outputs

Digital map libraries of fire behavior and fire effects. Each library consists of output for the 3 to 5 fire weather scenarios chosen.

Linkage to other models/tools

FEPF does not link directly to any other program; however, it is expected that most users will want quantitative measures of fire behavior, such as are currently modeled by FlamMap or FFE-FVS. Use of FireFamilyPlus greatly facilitates weather analysis, but is not critical. Additional inputs may be generated through use of a landscape dynamic simulation model. FEPF has been tested with the SIMPPLLE landscape dynamic simulation model, and could conceptually use output from FFE-FVS, RMLANDS or other vegetation simulators. Information on fire effects may be obtained from FOFEM, the URM, or the WHRM.

Developers (partners)	USDA Forest Service, Rocky Mountain Research Station
Current status	The framework has been developed through a pilot project on the Bitterroot National Forest. Subject to funding, additional implementation and training materials are scheduled.
Training availability	Training materials are being developed and tested during the early part of 2005. Additional training opportunities and distribution are planned, pending success of submitted funding proposals.
Technical documentation	Black, A.; Opperman, T. 2005. Fire effects planning framework: a user's guide. Gen. Tech. Rep. GTR-RMRS-163WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 63 p.
Contact	Anne Black 790 E Beckwith Ave. Missoula, MT 59801 (406) 329-2126 aeblack@fs.fed.us
Additional information	A Web site with additional background and information on demonstration sites, the draft user's guide, and a series of 2-page fact sheets describing various aspects of the FEPF is located at http://leopold.wilderness.net/research/fprojects/F005.htm.

Fire Effects Tradeoff Model (FETM)

Application for fuel treatment

Evaluates the effects of alternative land management practices, including fuel treatments, over long periods and under diverse environmental conditions and natural fire regimes.

Description

FETM is a disturbance model designed to simulate the effects of alternative land management practices on future landscape conditions over long periods and under diverse environmental conditions, natural fire regimes, and fuel and fire management strategies. The model is based on a stationary Markov formulation, which uses matrices of empirically determined probabilities to predict vegetation class replacement, and therefore composition, over time.

FETM accounts for natural and management-related disturbances. Natural disturbances include wildfire (for different fire intensity levels), insects and disease, and other user-specified disturbances. Management-related disturbances include harvesting, mechanical fuel treatments, prescribed fire, firewood collection, and other user-specified activities. Management activities and acres are scheduled in FETM. The user enters the number of acres by fuel characteristic class per year or range of years. Disturbance effects are represented as a change in surface loading, fuelbed configuration, vegetation age or structure, or any combination of the above.

FETM predicts annual changes in landscape composition and effects over any period ranging from 1 to 300 years. For each independent run, the starting composition in any year of simulation is linked to the previous year's results. The model is stochastic; random variables include wildfire frequencies in each of the four National Fire Danger Rating System weather classes, and potential wildfire size in the event that fuel loadings exceed the range of historical variability. FETM is a nonspatial

	model, capable of predicting disturbance effects within an area by vegetation class, but not capable of predicting where those impacts will occur on the landscape or whether the impacts are contiguous or dispersed.
	FETM uses fire behavior algorithms to determine size and intensity of fire events. It integrates aspects of physical fire behavior modeling into its simulations, rather than relying on historical fire data as the basis for determining future fire sizes and effects. Integration of fire behavior modeling allows FETM users to evaluate consequences of changes in fire environment (e.g., fuel loading, canopy structure, weather, topography) on wildfire area and other fire effects. For example, FETM can evaluate the effect of a change in surface fuel loading or stand configuration on the potential for crown fires. Integration of fire behavior modeling also offers an opportunity to quantify fuel consumption and smoke emissions over time.
Appropriate spatial scale	FETM was designed for large landscapes. A rule of thumb is that the modeling domain should be not less than 10 times the area of the largest fire that is expected to occur within the simulation period.
Analyst requirement	Requires a midlevel analyst or GIS specialist to run the model or tool or make it usable for local situations. More information on team requirements is available in the FETM users guide at: http://www.fs.fed.us/r6/aq/fetm/FETM_Downloads/Manual_060403.pdf.
Data inputs	Inputs include: √ Delineation of administrative units included in analysis area. √ Personal Computer Historic Analysis (PCHA) and Interagency Initial Attack Assessment (IIAA) database files for each included administrative unit (major source of required input data). √ Initial acres by fuel characteristic class (FCC). √ Fuelbed description for each FCC. √ Stand description (if applicable) for each FCC.

√ User-specific disturbance effects pathways and coefficients.
√ Mean fire frequency for low, moderate, high, and extreme NFDRS weather classes.
√ Relationship between expected final fire size and rate of spread from wildfire case history data.
√ Description of alternatives, including fire suppression program option.
√ Schedules of treatment activities, including prescribed fire.
√ Simulation period.
√ Number of model iterations over which to average results

Outputs	Graphical and tabular model outputs include: √ Annual landscape composition (acres by FCC). √ Annual wildfire acres, total and by fire intensity level. √ Annual fuel treatment acres (both targeted and accomplished). √ Annual smoke emissions from wildfire and prescribed fire (seven pollutants). √ Smoke emissions by prescribed fire treatment intensity in any future year. √ Net present value of future costs and benefits from wildfire and prescribed fire.
Linkage to other models/tools	FETM has the capability to link to administrative unit-specific PCHA and IIAA database files. In addition, FETM uses the key functionality and algorithms from several other state-of-the-science models, including Consume 2.1 (fuel consumption and emissions), CrownMass (predicting canopy structure and loading), BEHAVE (predicting crown fire rates of spread), PCHA (provides access to fire weather and history data; algorithms used to compute new weather-based outputs), IIAA (provides access to fire suppression organization costs and benefits data; algorithms used to compute new breakpoint rates of spread for fires burning in different

	derivative fuel models), and NFDRCalc (algorithms used to compute NFDRS fire output parameters), and others.
Developers (partners)	Forest Service, Pacific Northwest Region, Air Quality and Fire and Aviation Management Programs (Oregon State Office of the Bureau of Land Management, Air Sciences Inc.)
Current status	FETM is available to any organization or individual. A complete description of FETM, along with model setup files, user guide, technical documentation, brochure, and series of currently published papers are at http://www.fs.fed.us/r6/aq/fetm.
Training availability	Training is available as needed. For more information on training, please contact John Szymoniak or Mark Schaaf (see below).
Technical documentation	Available at http://www.fs.fed.us/r6/aq/fetm/FETM_Downloads/Technical%20Documentation_060403.pdf.
Contacts	John Szymoniak USDA Forest Service (208) 387-5748 jszymoniak@fs.fed.us or Mark Schaaf Air Sciences Inc. (503) 525-9394 ext. 11 mschaaf@airsci.com
Additional information	Two example FETM applications are found on the FETM Web site at: http://www.fs.fed.us/r6/aq/fetm/Applications.htm: (1) the Boundary Waters Canoe Area Wilderness fuel treatment final environmental impact statement, Superior National Forest, Minnesota (USDA FS 2001), and (2) an analysis of fuel treatment and fire suppression strategies for the Angeles National Forest, California (http://www.fs.fed.us/r6/aq/fetm/anf.htm). FETM is currently being applied at numerous other sites in the United States.

Fire Emission Production Simulator (FEPS)

Application for fuel treatment	FEPS is used to simulate fuel consumption, emission production, and plume buoyancy for prescribed burns and wildland fires under various meteorological conditions.
Description	FEPS is a dynamic simulation of fuel consumption, emission production, and plume buoyancy. It produces data concerning consumption, emissions, and heat release characteristics of prescribed burns and wildland fires. Total burn consumption values are distributed over the life of the burn to generate hourly emission and plume heat release information. The user can initiate a program run from a library of "typical" fuelbed and fire progressions or from previously stored user defaults, providing a means to compile or plan emission inventories. The size and growth rate of typical fires can be adjusted to fit local applications.
Appropriate spatial scale	FEPS is applicable at the scale of a wildfire or a prescribed burn, and can be used for most forest, shrub, and grassland types in North America and the world.
Analyst requirement	FEPS is designed for scientists and resource managers with some working knowledge of Microsoft Windows applications. The program allows users to produce outputs with very little input information by providing default values and calculations; advanced users can customize the data they provide to produce more refined results.
Data inputs	The FEPS interface allows the user to customize a burning or wildfire event. The user may enter or adjust default fuel loadings, fuel moistures, fuel consumption algorithms, fuelbed proportions. and fire growth rates to fit specific events or situations, and can specify diurnal changes in meteorological conditions that will modify plume rise. Many intermediate results are exposed to the user, and the user may accept these results or insert values of their own.

Outputs	FEPS provides a series of tabular reports and charts that document the results of a particular event. Results can be displayed in either "English" (Imperial) or metric (SI) units. Reports can be printed in a default format or exported as text or Excel files, and include the following: (1) consumption for each phase of the fire (flaming, short-term smoldering, and long-term smoldering); (2) emissions of carbon monoxide, methane, and PM2.5 for each hour of the event, and the drift percentage of PM2.5; and (3) buoyancy results for each hour of the event. Charts can be printed or exported as image files, and display the following: (1) consumption by combustion stage over the life of the event, (2) results of several plume rise calculations, (3) PM2.5 emissions over time, and (4) carbon monoxide emissions over time.
Linkage to other models/tools	None currently, but FEPS v. 1.1 will link with FCCS and BlueSky.
Developers (partners)	Forest Service Pacific Northwest Research Station (Hoefler Consulting Group, Seattle, WA)
Current status	FEPS version 1.0 can be downloaded at http://www.fs.fed.us/pnw/fera/feps/index.html.
Training availability	A Web-based tutorial will be available in 2006.
Technical documentation	The FEPS User's Guide can be downloaded from http://www.fs.fed.us/pnw/fera/feps/index.html.
Contact	Roger D. Ottmar USDA Forest Service (206) 732-7826 rottmar@fs.fed.us

Additional information — FEPS is an update to the Emissions Production Model (EPM) software. The original EPM was designed to help managers estimate and mitigate the rates of heat, particles, and carbon gas emissions from controlled burns of harvest-slash residue in Northwest forests. In updating EPM, a significant number of improvements were made to the usability, applicability, and accuracy of the model. The calculation approach was redesigned, and the model was renamed FEPS.

FireFamily Plus

Application for fuel treatment	Percentile weather can provide scientifically-based burning conditions for use in CrownMass, BehavePlus, NEXUS, and similar tools used to evaluate potential fire behavior. Data cannot be used by FFE-FVS. Wind data can be used to determine percentage of days winds are from a given quadrant and potential windspeeds for use in smoke dispersion analysis. Climatology analyses can aid in determining which weather elements are most closely associated with large fire growth.
Description	FireFamily Plus conducts analyses of historical fire weather and fire occurrence by using databases in the National Integrated Fire Management Interagency Database (NIFMID). Weather files can be extracted to prepare input data for the Rare Event and Risk Analysis Process (RERAP) or for FARSITE or for other uses.
Appropriate spatial scale	Mostly large watersheds (e.g., 5^{th}-field HUC); occasionally individual stations used for large to very large landscapes (e.g., 4^{th}-field HUC, ranger district/resource area and larger).
Analyst requirement	Moderate skill level is needed by analyst to examine weather and station catalog data for quality, to correct errors, and to interpret results.
Data inputs	√ Weather data files and station catalog files extracted from the interagency Weather Information Management System (WIMS) database. √ Data years to use for the analysis. √ Months and days to use in the analysis. √ Length of analysis period.
Outputs	Primary outputs of concern for fuel management are: √ Percentile weather √ Winds analysis
Linkage to other models/tools	Provides data for input into RERAP, FARSITE, CrownMass, and NEXUS.

Developers (partners)	Forest Service, Department of the Interior, Systems for Environmental Management.
Current status	Program is fully functional. Go to http://www.fire.org/ for additional information.
Training availability	Use of FireFamily Plus is taught in S-491 Intermediate National Fire Danger Rating System. See http://www.nationalfiretraining.net for class dates and locations. Course guides can be purchased from the National Wildfire Coordinating Group's Publication Management System.
Technical documentation	None
Contact	For technical support: Fire and Aviation Management System Help Desk (800) 253-5559 fire_help@dms.nwgc.gov
Additional information	When coupled with data on fire occurrence, users can analyze area-specific weather conditions associated with large fire spread. Analysis of fire occurrence data also provides information on predominant statistical causes and distribution of fire size classes to support purpose and need statements. Weather data for some stations extend into the 1960s; however, data prior to the mid-1970s is usually incomplete and can result in erroneous output. Weather data must be checked for quality, with errors removed or corrected. Days with incomplete data should be completed if possible, or deleted. Missing records affect resulting analyses. Weather and fire occurrence data sets analyzed for use in fire planning usually have had errors corrected and are preferred over raw data extracted from WIMS. Weather records covering at least 20 years are preferred. Note that there are differences in long-term weather patterns at the decadal scale, so the data period used

can affect the output. Stations with less than 10 years of data should be used cautiously and avoided if possible. Data from older manual stations and newer Remote Automated Weather Stations (RAWS) can be merged through use of a Special Interest Group (SIG) and analyzed.

A strong correlation exists between large fire growth-days and 100-hour fuel moisture and energy release component (ERC) for the G model. Critical values for 100-hour fuel moistures and ERC are listed as part of predictive analyses for 10-day and seasonal fire danger and posted in the "Predictive Services" section of most Geographic Area Coordination Centers in the Western United States (e.g., see http://www.nwccweb.us/predict/index.asp). FireFamily Plus allows for analyses using both variables simultaneously to estimate the number of days when large fire growth is possible.

Fire and Fuels Extension-Forest Vegetation Simulator (FFE-FVS)

Application for fuel treatment	Silviculturists have long used FVS to analyze forest growth and yield under a variety of treatment options. FFE allows the user to evaluate potential fire behavior and stand mortality and resulting effects on snag longevity and subsequent tree growth.
Description	FFE-FVS simulates the effects of fire on forest structure, and the effects of different treatments on fire potential.
Appropriate spatial scale	Forest stands to small watersheds (mostly 6th-field HUC and smaller), but can be cautiously aggregated to larger scales.
Analyst requirement	Requires an experienced user to run the model and produce usable results. Users should be familiar with the concepts used in FVS and the data used to develop snag longevity and surface fuel loading outputs. These outputs are based on a mix of scientifically based equations and expert judgment.
Data inputs	Forest stand attribute data are required to initialize a run of FVS. Users can also provide: √ Detailed snag records √ Adjustments to defaults for snag breakage rates, decay rates, fall rates, and burn-up rates √ Initial surface fuel loading √ Adjustments to decay rates and duff production rates √ Custom fuel models √ Static or dynamic fuel models √ Changes in fuel loading resulting from mechanical treatments such as crushing; burning conditions √ Fuel moistures √ Windspeed √ Pile burning √ Flame adjustment factors
Outputs	√ Images of resulting stand structures before and after treatment and fires. √ "Movies" of fires burning through stands.

	√ Graphs of potential surface fire flame length, crowning index, surface fuel loadings, snag numbers, canopy cover, stand structure, canopy ceiling height, and timber volume through time. √ Detailed or summary reports of snags, surface fuels; type of fire; scorch height; tree mortality; and fuel consumption.
Linkage to other models/tools	Tree tables generated by FVS can be imported into CrownMass. "Cut lists" for trees removed by thinning can be used directly by My Fuel Treatment Planner, Understory Response Model, and Wildlife Habitat Response Model.
Developers (partners)	Forest Service Rocky Mountain Research Station (Joint Fire Science Program)
Current status	Model is fully functional at http://forest.moscowfsl.wsu.edu/4155/ffe-fvs.html. Variants are available for all portions of the Western United States.
Training availability	Training is periodically available through the U.S. Department of Agriculture, Forest Service, Forest Management Service Center in Fort Collins, CO. http://www.fs.fed.us/fmsc/fvs/training/index.php.
Technical documentation	Dixon, G. 1998. Evaluating stand density management alternatives using the Forest Vegetation Simulator. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Forest Management Service Center. 16 p. http://ftp.fs.fed. us/pub/fmsc/ftp/fvs/docs/gtr/canpap.pdf. Reinhardt, E.D.; Crookston, N.L. 2004. The fire and fuels extension to the Forest Vegetation Simulator. Gen. Tech. Rep. RMRS-GTR-116. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 209 p.

Contacts	Elizabeth Reinhardt USDA Forest Service (406) 329-4760 ereinhardt@fs.fed.us or Nicholas Crookston USDA Forest Service (208) 882-3507 ncrookston@fs.fed.us
Additional information	FFE-FVS produces different crown fire results than CrownMass and NEXUS and different estimates of mortality and fuel consumption than FOFEM. Results can be skewed because FFE works on a 1-year time step and FVS works on a 5- to 10-year time step. Live fuels are poorly represented in FFE-FVS. Decomposition rates are not sensitive to aspect, elevation, or potential vegetation type.

Fire Regime Condition Class (FRCC)

Application for fuel treatment	At the 6th-field HUC scale or equivalent, FRCC can aid in determining stand types on which to focus treatment. At the 5th-field HUC scale or equivalent, it can aid in prioritizing 6th-field HUCs and fire regimes as well as stand types on which to focus treatment. At the 4th-field HUC scale or equivalent, it can aid in prioritizing 5th-field HUCs and fire regimes for treatment.
Description	FRCC is an interagency, standardized tool for determining the degree of departure from presettlement vegetation, fuel, and disturbance regimes. Assessing FRCC can help guide management objectives and set priorities for treatments.
Appropriate spatial scale	Originally designed for large scale (e.g., 4th-field HUC) but being applied at all scales; very coarse classifications.
Analyst requirement	Moderate to high; the FRCC process is intended to be completed by a team including a vegetation management specialist with expertise on successional concepts and a fuel management specialist with expertise on fire ecology. Although not required by the tool, maps of stand types and fire regimes can aid in determining fire regime condition class.
Data inputs	√ Regsitration code √ Several project area identifiers and descriptors √ Several biophysical setting descriptors for the landscape and each stratum √ Reference fire frequency and severity for each stratum √ Current fire frequency and severity for each stratum √ Breakpoint between open and closed canopy (defaults are provided) √ Reference percentages of five vegetation-fuel classes for each stratum √ Current percentages of five vegetation-fuel classes plus any percentages of uncharacteristic vegetation-fuel classes for each stratum

Outputs	√ Departure from reference conditions for vegetation-fuel fire frequency, and fire severity for each stratum √ FRCC by vegetation-fuel and fire frequency and severity for each stratum √ Weighted mean reference condition and class for fire frequency and severity √ Landscape natural fire regime group √ Landscape weighted mean departure for vegetation-fuel, fire frequency, and fire severity √ Landscape FRCC √ Graph of stratum and landscape FRCC
Linkage to other models/tools	No direct linkage to other models and tools. The Fuel Characteristic Classification System (FCCS) can be used to describe different seral structure stages–present, past, and desired. LANDFIRE is expected to produce maps of FRCC at 30-m resolution in the Western United States by 2009.
Developers (partners)	U.S. Department of Agriculture, Forest Service; Bureau of Land Management; National Park Service; Fish and Wildlife Service; Bureau of Indian Affairs; U.S. Geological Survey (The Nature Conservancy)
Current status	The second generation guidebook and methods are available. Baseline reference conditions for historical seral stages have been developed for most historical cover types in the continental United States. For additional information, see http://www.frcc.gov.
Training availability	Online training and certification is available at http://www.frames.gov/frcc. Various training opportunities are offered by federal agencies throughout the United States.
Technical documentation	Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p. + CD-ROM.

Contacts	For answers related to methods and procedures, contact helpdesk@frcc.gov or Wendel Hann USDA Forest Service (505) 388-8243 whann@fs.fed.us
Additional information	Example analyses using FRCC are available at http://www.frcc.gov. Although nonspatial in nature, the overall approach can include spatial considerations. The FRCC process is biased toward dry forests with short fire-return intervals. At longer fire-return intervals, the process is less effective, because it is unlikely a large landscape will meet the size requirements specified in the process, or have all five seral stages present at any given time. In long-interval, high-severity fire regimes, time since the last ecologically significant disturbance is more important than spatial arrangement of different seral stages. One seral stage is likely to dominate the landscape at any given time. These considerations are not included in the reference baselines. Adequate explanations of how to use the uncharacteristic seral stages are not available. These "stages" include a mix of spatial considerations, other disturbance types, patch sizes, and road densities. The FRCC process has undergone extensive peer review that resulted in considerable changes in the terminology, procedures, and methods in the first 2 to 3 years of its development. Users who attended the initial classes may be using out-dated methods and terminology. For example, "potential vegetation" is now called "biophysical setting." The current version of the software now includes a GIS-based process (mapping tool) to automate inputs of current conditions.

Because each seral stage can be assigned other resource values, such as hydrological function or habitat for a given species, the FRCC process provides a method to integrate other resource considerations and to examine how the mix of environmental functions and services may change among historical, current, and desired conditions.

Fireshed Assessment: An Integrated Approach to Landscape Planning

Application for fuel treatment

Fireshed assessments are used to:

- √ Develop a program of work—Interdisciplinary teams use a logical, step-by-step process to design, test, and schedule fuel and vegetation management projects to meet multiple resource objectives.
- √ Ensure forest plan consistency—A Fireshed assessment documents a strategic design of treatments across the fireshed, demonstrating consistency with forest plan strategies for managing fire and fuels, and National Fire Plan goals for reducing hazardous fuels, protecting communities, and restoring fire-adapted systems.
- √ Invite interagency and public participation at an early stage in the planning process—Fireshed assessments alone do not result in decisions. Assessments identify opportunities for projects, making them a platform from which interagency partners, collaborators, stakeholders, and the public can participate in developing and testing treatment designs.
- √ Assess cumulative effects—As part of the fireshed assessment process, interdisciplinary teams look at potential changes in fire behavior, habitat, and watershed conditions. The results from these tests can ultimately feed into cumulative effects analyses that are conducted as part of site-specific project planning.

Description

Firesheds are large (thousands of acres) landscapes, delineated based on fire regime, condition class, fire history, fire hazard and risk, and potential wildland fire behavior. Fireshed assessment refers to an interdisciplinary and collaborative process for designing and scheduling site-specific projects consistent with goals of the Healthy Forests Restoration Act of 2003, National Fire Plan, and national forest land and resource management plans. Steps in the fireshed assessment process include:

	√ Delineate firesheds. √ Select a fireshed for assessment based on national, regional, and forest priorities. √ Describe goals and desired conditions. √ Describe existing conditions for fire behavior, habitat, forest health, and community protection. √ Identify opportunities and project proposals to move the existing landscape toward desired conditions for fire behavior, forest health, and habitat.
Appropriate spatial scale	Medium to large landscapes (e.g., 4th- and 5th-field HUC) to allow managers to assess progress toward meeting: √ National Fire Plan goals to (1) reduce hazardous fuels to reduce the risk of unplanned and unwanted wildland fire to communities and to the environment, and (2) restore, rehabilitate, and maintain fire-adapted ecosystems. √ Local planning goals relative to fire, fuel, and habitat, such as (1) strategically place treatment areas across landscapes to interrupt potential wildland fire spread, and reduce the extent and severity of fires, and (2) improve the continuity and distribution of old forest across landscapes.
Analyst requirement	Fireshed assessments consider an array of desired conditions and environmental changes in a spatially explicit manner. As such, they require a moderately high level of GIS, fire behavior modeling, silviculture, programming, and analytical support.
Data inputs	To model changes in fire behavior by using FARSITE, fireshed assessments use the following raster landscape themes: elevation, slope, aspect, fuel model, canopy cover, canopy height, crown base height, crown bulk density, duff loading, and coarse woody material. Fire weather variables are also used as data inputs. Changes in vegetation, habitat, and treatment costs are assessed by using the following raster landscape

	themes: California Wildlife Habitat Relationships types, vegetation type, tree size, canopy cover, protected activity centers, California spotted owl home range core areas, treatment prescriptions, tree lists, volume, and biomass potential. Timber stumpage values are also used as input variables to assess treatment costs.
Outputs	Fireshed assessments spatially display opportunities for meeting multiple objectives (reducing the size and severity of wildland fires, enhancing resilience of forest stands to insect- and drought-related tree mortality, and conserving habitat for at-risk wildlife species). The assessments also provide a spatially explicit, preliminary assessment of changes in fire behavior, vegetation, habitat, and economics under different scenarios, with each scenario designed to move existing fireshed conditions toward desired conditions.
Linkage to other models/tools	Fireshed assessments rely on a variety of tools, including FVS, FARSITE, FLAMMAP, and ArcGIS tools such as focal mean. The products from a fireshed assessment can be linked to various reporting systems, including FACTS, NFPORS, My Fuel Treatment Planner, and treatment scheduler.
Developers (partners)	Forest Service, Pacific Southwest Region
Current status	A regional cadre of resource specialists has been working to develop, test, and refine the fireshed assessment process. The cadre has conducted beta tests of the fireshed assessment process during workshops with the Modoc, Mendocino, and Stanislaus National Forests. The remaining forests in the Pacific Southwest Region are scheduled for workshops. At each workshop, the cadre works through the fireshed assessment process with a forest or district interdisciplinary team on an actual fireshed. The cadre members complement the skills and experience of the workshop interdisciplinary team, acting as an extension of the team and filling gaps. The cadre provides “real time”

	spatial analysis products displaying changes in fire behavior, habitat, and economics and helps the team learn how to produce similar products. After the workshop, the cadre continues to provide advice and support to workshop participants to facilitate refinements to their assessments.
Training availability	None.
Technical documentation	None.
Contact	Bernie Bahro USDA Forest Service (916) 640-1066 bbahro@fs.fed.us
Additional information	The Washington Office of the Forest Service has sponsored a pilot project to test Fireshed in other national forests outside the Pacific Southwest. Reports from the pilot projects are expected in 2006.

First Order Fire Effects Model 5.2 (FOFEM)

Application for fuel treatment	Potential uses include wildfire impact assessment, development of timber salvage specifications, design of fire prescriptions, analysis of first-order treatment effects in environmental analyses, and fire management planning.
Description	FOFEM predicts fuel consumption, soil heating, smoke production, and tree mortality. The model contains a planning mode for prescription development.
Appropriate spatial scale	Primarily stand scale but can be used for smaller watersheds (e.g., 6^{th}-field HUC).
Analyst requirement	A low-level analyst can run FOFEM. It is nonspatial.
Data inputs	√ Mortality—Region (Interior West, Pacific West, Northeast, Southeast); general burning conditions (low to extreme); for each species and d.b.h. class species, density (trees/acre), d.b.h., tree height, crown ratio; and flame length or scorch height. √ Fuel/smoke/soil—Region; cover classification system (SAF/SRM, NVCS, FCC); cover type; season of burn; general burning condition (low to very high); fuel type (natural, slash, or piles); fuel loading by size class (litter, 0-¼, ¼-1, 1-3, 3+ inch; duff, herb, shrub, foliage, branchwood) with adjustments permitted from defaults (typical, light or sparse, heavy or abundant); fuel moisture for ¼-1 and 3+inch woody fuels, and for duff; percentage of 3+ inch that is rotten and how it is distributed; duff depth and type of duff moisture (entire, lower, NFDR, adjusted NFDR); and percentage of crown burned. The soil module also includes soil texture and soil moisture percentage.

Outputs	√ Mortality—Percentage of tree mortality by species and size class, and pre- and postfire canopy cover. √ Fuel—Preburn loading, consumed loading, postburn loading, percentage reduction, duff depth consumed, percentage mineral soil exposure. √ Smoke—Same as fuel outputs, plus emissions for PM10, PM2.5, carbon monoxide, carbon dioxide, sulfur oxides, nitrogen oxides, and methane from flaming and smoldering combustion; total consumption in flaming and smoldering combustion; and duration of flaming and smoldering combustion. √ Soil—Same as fuel, plus soil layer maximum temperatures and duration of heating at 0 to13 cm (0 to 5 inch) depth by 1-cm increments, maximum depth reaching 60 °C (140 °F), and maximum depth reaching 275 °C (527 °F).
Linkage to other models/tools	No current linkages, but a possible linkage to Fuel Characteristic Classification System may be added in the future. BehavePlus and FOFEM may merge into a single tool in the future.
Developers (partners)	Rocky Mountain Research Station (Systems for Environmental Management)
Current status	Fully functional
Training availability	No formal training is available. Self-directed tutorials can be downloaded from http://www.fire.org.
Technical documentation	None.
Contacts	Elizabeth Reinhardt USDA Forest Service (406) 329-4760 ereinhardt@fs.fed.us or Robert Keane (406) 329-4846 rkeane@fs.fed.us

Additional information | One of the best uses of FOFEM currently is to evaluate potential soil heating with and without salvage in dry forests burned with uncharacteristic severity. Equations used in FOFEM to estimate scorch and mortality are more robust than those used in FFE-FVS; the equations are the same as those used in BehavePlus. Scorch and mortality information may be displayed in a more useful format in FOFEM than in BehavePlus, although BehavePlus produces graphs as well as tables.

FlamMap 3.0 Beta 6

Application for fuel treatment	FlamMap can be used to identify those portions of the landscape where expected fire behavior and certain fire effects are potentially within or outside of acceptable levels, indicating where fuel treatments may be justified. The Minimum Travel Time tool allows the user to determine the fastest pathways of fire travel under specified weather and wind conditions. The Treatment Optimization Model allows the user to identify treatment locations and sizes needed to disrupt the fastest pathways.
Description	FlamMap is a spatial fire behavior tool, where an entire landscape is analyzed by using a single set of wind and weather conditions. It creates raster maps of potential fire behavior characteristics (rate of spread, flame length, crown fire activity, etc.) and environmental conditions (dead fuel moistures, midflame windspeeds, solar irradiance) and minor and major travel paths over an entire landscape. FARSITE landscapes may be imported or landscapes can be assembled from the needed input layers within FlamMap. Use of the Minimum Travel Time and Treatment Optimization Model tools is enhanced through the use of gridded winds, which adjust input windspeeds and direction based on terrain, soon to be readily available through Wind Wizard. The output maps can be viewed in FlamMap or exported for use in a GIS, image processor, or word processor.
Appropriate spatial scale	Small watersheds (e.g., 6th-field HUC) to large land scapes (4th-field to 5th-field HUC).
Analyst requirement	Users can readily teach themselves how to use FlamMap. The current version does not contain help files for the Minimum Travel Time and Treatment Optimization

Model tools. As a result, some input variables are not made clear to the user. Others are not readily apparent, but can eventually be deduced by experimenting with the model inputs. FlamMap is organized in an expanding tree structure rather than a command-and-menu structure.

Developing input layers can require a high level of expertise for the user or GIS support staff. Most data layers are created through remote sensing to provide wall-to-wall coverage at the same resolution. The usefulness of FlamMap increases greatly when the data layers include inholdings and adjacent lands.

Data inputs

FlamMap uses the same base data layers as FARSITE, of which five are mandatory and three are optional. These layers must be in raster format and are combined to create a landscape file.

√ The five mandatory layers are slope, aspect, elevation, canopy cover, fuel model.

√ The three optional layers are canopy base height, canopy ceiling height, canopy bulk density. These layers are needed to include spotting from torching trees and crown fire simulation. In the absence of these three layers, the models assume fully stocked stands of fully crowned Douglas-fir.

FlamMap can use the 13 standard fuel models as well as the new models released by Scott and Burgan (2005).

Outputs

Outputs can be specified and consist of maps in exportable form. The Minimum Travel Time and Treatment Optimization Model tools also create three outputs pertaining to elliptical spread, although these outputs are not explained in the help files.

Linkage to other models/tools

FlamMap uses FARSITE landscape files and can use FARSITE wind and weather files. In the future, FlamMap will be able to use gridded wind files developed by using Wind Wizard.

Developers (partners)	Rocky Mountain Research Station (Systems for Environmental Management)
Current status	FlamMap 2.0 is available; FlamMap 3.0 is in beta test model. For more information see http://www.fire.org.
Training availability	Currently, there is no training and no online tutorial for FlamMap.
Technical documentation	Stratton, R.D. 2004. Assessing the effectiveness of landscape fuel treatments on fire growth and behavior. Journal of Forestry. 102(7): 32-40.
Contact	Mark Finney USDA Forest Service (406) 329-4832 mfinney@fs.fed.us
Additional information	FlamMap is not a replacement for FARSITE or a fire growth simulation model. There is no temporal component in FlamMap. It uses spatial information on topography and fuels to calculate fire behavior characteristics at one instant. Auxiliary grid and vector files for features such as roads, streams, point locations, etc. can be imported and displayed, but have no effect on the outputs. FlamMap does not display polygons as filled, but only as outlines. Unlike FARSITE, the current version of FlamMap does not recognize barrier files. Wind and weather inputs are required. Winds may be specified within the model, imported as FARSITE wind file, or imported as gridded winds. Weather files can be used to condition fuels ahead of the simulation run to adjust 1-hour fuel moistures by aspect, elevation, and shading. Use of a fire start location or line of fire is optional, depending on the type of analysis being conducted.

Forest Inventory and Analysis Biomass Summarization System (FIA BioSum)

Application for fuel treatment	Used to identify promising locations for woody biomass-fired electrical generation plants and conventional wood processing facilities, and to assess costs/revenues of treating broad landscapes under various assumptions, objectives, and scenarios. The effectiveness and economic attractiveness of numerous alternative prescriptions can be compared and evaluated with respect to a large, representative sample of the forested landscape. Individual land management units, ecoregions, and whole states can be compared and contrasted with respect to the scope of current fuel hazard, the extent to which fuel treatments can pay for themselves, and the extent to which fuel treatments can reduce fire hazard.
Description	This framework combines and integrates the publicly available models FFE-FVS and STHARVEST with forest inventory plot data and digital representations of road networks. It simulates implementation of a wide range of fuel treatments at large spatial scales, costs of treatments, fire hazard reduction, mix of merchantable and nonmerchantable wood products generated by treatments, and "hot spots" of woody material that could merit processing facilities. Nearly any objective function and constraint set can be specified to analyze fuel treatment feasibility. Results represent fuel reduction opportunities, costs and yields for entire forested landscapes, based on FIA plots that represent a sample of all forest types and conditions on all ownerships.
Appropriate spatial scale	Very large forest landscapes (10,000 square miles and larger)
Analyst requirement	A high level of analyst sophistication and experience is required to use the current version of this tool; efforts are underway to make it accessible to midlevel analysts.

Even then, users will need to be familiar with generating prescriptions in FVS, interpreting outputs from FFE, and (optionally) carrying out standard geoprocessing activities with ArcInfo or ArcGIS via execution of Arc macro language scripts (AMLs) in Grid and Arc environments if detailed representation of haul costs is desired.

Data inputs

√ Standard FIA inventory plot, condition, and tree data, including at least fuzzed plot locations.

√ A complete road network for the study area (precise connectivity not required) attributed with road speed classes (3 to 5 classes are usually sufficient).

√ Land ownership/designation/status GIS layers and decision rules that determine which acres may be treated, which areas can host processing facilities, and over which areas fuel treatment yields may be transported.

√ A set of standardized fuel treatments by forest type that can be broadly applied within the FVS framework.

√ A set of potential processing sites at which woody biomass or merchantable wood processing facilities may be considered for construction, or a set of rules for generating such locations.

√ Objectives and constraints to be applied either heuristically or via an optimization framework (e.g., treat all acres where torching index and crowning index can be improved from below 15 miles per hour to above 15 miles per hour, and pick the treatment for each acre that maximizes net revenue, but only if net revenue is greater than -$200 per acre).

Outputs

Area treated, total net revenue (or cost), amount of biomass and merchantable-size material that would arrive at each simulated processing site; the best prescription associated with each inventory plot, and the amount of hazard reduction achieved.

Linkage to other models/tools	Framework integrates FFE-FVS, STHARVEST, FIA data; may ultimately be linked with GNNfire to produce wall-to-wall maps of fuel treatment effects (e.g., hazard reduction in every pixel).
Developers (partners)	Forest Service Pacific Northwest Research Station (Forest Service Pacific Southwest Research Station, Southwestern Region)
Current status	Proof of concept essentially complete. Analysis for northern California and western Oregon complete and being documented in a research paper. Analysis for Arizona and New Mexico ongoing. See http://www.fs.fed.us/pnw/fia/biosum for more information and links to articles.
Training availability	Not currently available. User manual anticipated in winter 2006 followed by training sessions if interest warrants.
Technical documentation	See http://www.fs.fed.us/pnw/fia/biosum.
Contact	Jeremy Fried USDA Forest Service (503) 808-2058 jsfried@fs.fed.us
Additional information	None.

Fuel Characteristic Classification System (FCCS)

Application for fuel treatment

- √ Map fuelbeds with associated fuel characteristics and fire potentials, and input fuelbed characteristics into various fire behavior and fire effects models for fire planning and assessing fuel treatment activities.
- √ Quantitative measure of effectiveness of fuel or vegetation treatment for reducing fire potential, and may be used to plan and prioritize fuel treatments or to monitor changes on a landscape over time. Can be an alternative to using change in Fire Regime Condition Class as the sole performance measure.
- √ Characterization and quantification of landscapes for the purpose of assessing the effects of fuel treatments, e.g., a spatial layer of fuel loadings or FCCS fire potentials before and after the implementation of a fuel treatment.

Description

FCCS assigns fuel properties and fire potentials to landscapes at all scales across the United States. FCCS consists of a large database of physical parameters that describe the abundance, physical character, and arrangement of wildland fuelbeds. The database currently includes 220 fuelbeds common in the United States. The FCCS stratifies fuelbeds into 6 horizontal fuelbed strata that represent unique combustion environments and 16 fuelbed categories with common combustion characteristics.

FCCS also includes an expert system to interactively (1) select fuelbed prototypes by inputting location, vegetation form, structure, cover type, change agent, fire regime, and condition class and (2) customize fuelbeds in the database to site-specific data. It also contains a calculator to generate fuelbed characteristics and fire potentials (the intrinsic capacity of the fuelbed for surface fire behavior, crowning potential, and fuel consumption) for each fuelbed.

Appropriate spatial scale	All.
Analyst requirement	FCCS is simple to run. Identifying and constructing fuelbeds to represent the area to be assessed requires a midlevel fuels or fire management specialist. Standard fire potentials are calculated automatically. Customized fire potentials require interaction between a user and the FCCS development team.
Data inputs	At a minimum, FCCS requires users to: √ Identify the Bailey's ecoregion and vegetation form of the assessment area. √ Select the fuelbed prototype that most closely represents fuelbeds within the assessment area. √ Accept a fuelbed prototype or customize the selected fuelbed by adjusting variables assigned for each fuelbed category with inventory data.
Outputs	√ Quantitative fuel characteristics (physical, chemical, and structural properties) based on user input. √ Fire potential based on the intrinsic capability of the fuelbed for surface fire behavior, crowning potential, and fuel consumption. Several basic output reports are available including: √ Fuelbed name and description. √ All input information provided by the user or inferred by the FCCS. √ All fuel characteristics generated by the system including fuel loading and fuel area index. √ Fire potential, NFDRS and fire behavior fuel model assignments. The fire hazard potential of any fuelbed is represented as a three-digit rating, e.g. "582" where the three digits represent (1) potential surface fire behavior (on a scale from 1 to 9), (2) potential crown fire potential (1 to 9), and (3) potential available fuel (or carbon) (1 to 9). Nine optional fire potentials are calculated automatically, and others may be added or customized for the user by developers.

	√ Reliability or data quality index.
Linkage to other models/tools	FCCS will be linked to several models that require fuel characteristics as inputs including Consume 3.0, FOFEM, and FVS.
Developers (partners)	Forest Service Pacific Northwest Research Station (Forest Service Pacific Northwest Region, Forest Service Forest Inventory and Analysis program, Joint Fire Science Program, National Fire Plan, National Park Service, Bureau of Land Management)
Current status	FCCS version 1.0 has been released, and can be downloaded at http://www.fs.fed.us/pnw/fera/fccs.
Training availability	A Web-based tutorial will be available in 2006; see http://www.fs.fed.us/pnw/fera/fccs.
Technical documentation	Sandberg. D.V.; Ottmar, R.D.; Cushon, G.H. 2001. Characterizing fuels in the 21st century. International Journal of Wildland Fire. 10: 381-387. Ottmar, R.D.; Sandberg, D.V.; Riccardi, C.L.; Prichard, S.J. [In preparation]. An overview of the Fuel Characteristic Classification System—quantifying, classifying, and creating fuelbeds for resource planners. Riccardi, C.L.; Andreu, A.G.; Elman, E.; Kopper, K.; Long, J.; Ottmar, R. [In preparation]. National system to characterize physical properties of wildland fuels. Riccardi, C.L.; Sandberg, D.V.; Prichard, S.J.; Ottmar, R.D. [In preparation]. Calculating physical characteristics of wildland fuels in the Fuel Characteristic Classification System. Sandberg, D.V.; Riccardi, C.L.; Schaaf, M.D. [In preparation]. Fire potential rating for wildland fuelbeds using the Fuel Characteristic Classification System.
Contact	Roger Ottmar USDA Forest Service (206) 732-7826 rottmar@fs.fed.us

Additional information

FCCS can be used to map fuelbeds, their characteristics, and intrinsic fire potential. A manager may want to prioritize and measure the effectiveness of fuel treatments across an assessment region. By mapping a combination of selected and customized fuelbeds from the FCCS with the associated fire behavior (FB), crown fire (CF), and available fuel (AF) potential index (1 to 10, with 10 being the highest), decision-support and performance measures for the vegetation and fuel treatments can be assessed for fire hazard reduction and improved Fire Regime Condition Class distribution.

Fuel Characteristic Classification System (FCCS) Fuelbed Mapping

Application for fuel treatment	Mapping fuelbeds to assess effects of fuel treatments
Description	Characterization and quantification (through links to FCCS) of landscapes for the purpose of assessing the effects of fuel treatments, e.g., a spatial layer of fuel loadings or FCCS fire potentials before and after the implementation of a fuel treatment. Rule sets and knowledge base for associating FCCS fuelbeds with spatial location. Used for modeling consumption and emissions from prescribed and wildland fires.
Appropriate spatial scale	Applicable at any spatial scale up to 1 km for which adequate vegetation and environmental data exist. Useful for regional-scale modeling of air quality (coarse scale) or for modeling fire hazard, fire potentials, and fire effects at stand, landscape, or forest/district scale.
Analyst requirement	FCCS is simple to run. However, mapping FCCS fire potentials across a landscape requires a GIS analyst, database manager/programmer, and fuel specialist. At the unit or subunit level, input is needed from local managers. At the watershed or larger scale, spatial statistics may be needed.
Data inputs	√ Select the fuelbeds that most closely represent fuelbeds within the assessment area. Mapping across areas without detailed fuel or spatial data requires: √ GIS layers for vegetation, potential vegetation, or biophysical setting, and land use. √ Definition of FCCS fuelbeds associated with each portion of the landscape to be mapped.
Outputs	If fuelbeds before and after treatment are identified: √ Mapped and statistically-represented change in fire hazard after treatment or natural event.

	If spatial information is also available: √ Mapped layers of FCCS fuelbeds at any scale from stand to landscape or continental, from natural disturbance or management treatments.
Linkage to other models/tools	Used in conjunction with FCCS, CONSUME and FEPS, vegetation succession models (e.g., VDDT, FVS), fire-effects tradeoff models, the Landscape Management System (LMS), or any other tool that accepts spatial data layers of fuels.
Developers (partners)	Can best be accomplished through active partnership among FCCS development team, other scientists, and resource managers.
Current status	Applied at coarse scale (1 km or 0.62 mile) across the Western United States. There is an ongoing partnership to provide initial application at the regional scale (Pacific Northwest national forests and districts).
Training availability	Training provided through workshops and as requested.
Technical documentation	McKenzie, D.; Andreu, A.G.; Norheim, R.A.; Bayard, A.R.; Kopper, K.E.; Elman, E. [In preparation]. Mapping fuels across the conterminous United States for coarse-scale modeling of fire effects.
Contact	Don McKenzie USDA Forest Service (206) 732-7824 donaldmckenzie@fs.fed.us
Additional information	None.

Fuels Management Analyst Plus (FMA Plus)

Application for fuel treatment	DDWoodyPC calculates fuel loading by size class for use in assigning fuel models and assessing general fuel loadings by using either data collected through Brown's planar intercept fuel inventory method or photo series data used as sample data. CrownMass assesses pretreatment crown fire risk, effects of stand thinning, and post-treatment crown fire risk with or without subsequent fuel treatment.
Description	FMA Plus is used to determine dead, down woody fuel loading by using either Brown's inventory methods or photo guides, to assess crown fire risk, and to predict slash resulting from thinning and logging operations. The tool consists of three modules: (1) DDWoodyPC for estimating dead, downed woody fuel; (2) Photo Series Explorer to view scanned images of older photo guides to fuel loadings; (3) CrownMass to predict crown fire risks and estimate slash loadings, and Fuel Model Manager to create custom fuel models for use in CrownMass.
Appropriate spatial scale	Primarily stand scale but can be used to assess small watersheds (e.g., 6th-field HUC).
Analyst requirement	Moderate level of analytical skill needed, nonspatial in nature, but can be applied to several stands and mapped. For down woody fuel estimates, users should be familiar with Brown's fuel inventory methods and equations. For crown fire risk assessment and slash predictions, users should be familiar with common stand exam procedures, equations that support debris prediction or the former DEBMOD (DEbris MODification) program used on the Forest Service Data General computer system, and elements of the fuel complex associated with the start and spread of crown fires.
Data inputs	For DDWoodyPC: √ Slope

√ Number of pieces counted in 0-¼, ¼-1, and 1-3-inch size classes
√ Two duff depths
√ Diameter of each sound and rotten piece >3 inches diameter
√ Three fuel bed depths
√ Predominant species

For CrownMass:
√ Merchantable tip diameter
√ Slope steepness (in two locations)
√ For each tree: plot ID, tree number, diameter breast height, species, height, crown ratio, trees per acre, structure stage, proportion in crown of foliage through 1,000-hour fuels, proportion cut, proportion deposited on surface, proportion of boles left, percentage rotten, equation set (Intermountain or Pacific Northwest coast), surface fuel loading, fuel moistures, 20-foot windspeed, wind adjustment factor, burn day temperature.

Outputs

DDWoodyPC:
√ Fuel loading by size class and total loading.
CrownMass:
√ Statistics and graphs on canopy and surface loadings
√ Graphs and data on canopy characteristics by plot
√ Expected fire behavior
√ Canopy bulk density
√ Critical flame length and fireline intensity to initiate crowning
√ Rate of crown fire spread and rate needed for active crowning
√ Fire type (surface, passive crown fire, active crown fire), scorch height, and probability of mortality and percentage crown scorch by species and diameter.

Linkage to other models/tools

Can use tree tables developed through the Forest Vegetation Simulator as input files for CrownMass.

Developers (partners)

Don Carlton, Fire Program Solutions, a private vendor

	(using existing information from federal agencies and publications)
Current status	Tool is fully functional and supported by Fire Program Solutions. Future versions will include newer photo guides and enhancements to crown fire assessment based on current research. Available for purchase at http://www.fireps.com/fmanalyst/fmasupport.htm.
Training availability	Training is potentially available by arrangement with Fire Program Solutions.
Technical documentation	No direct documentation. Based on previous publications and user's guides.
Contact	Don Carlton Fire Program Solutions LLC dcarlton@fireps.com (503) 668-1390
Additional information	Crown fire results differ from the results provided through NEXUS and FFE-FVS and possibly BehavePlus. When stand exam data are available, CrownMass provides a method to test different cutting prescriptions if reduction of crown fire risk is an objective. For large landscapes, representative stands can be sampled and evaluated and results applied to similar stands to determine patterns and identify target areas for treatment when data layers are not available to support the use of FlamMap, or landscape sizes are too small for effective use of FlamMap. The program allows many adjustments to account for site differences. Defaults are provided for many of these potential adjustment factors. For example, users can adjust canopy loadings based on structural stage (co-dominant, intermediate, suppressed). The model contains variations on both the fire behavior prediction system and NFDRS fuel models where loading and fuelbed depth have been adjusted up and down by one-third, and some custom models, providing 109 “standard” fuel models.

Gradient Nearest Neighbor (GNN) Method and Software for Regional Mapping of Vegetation and Fuels

Application for fuel treatment	Maps of fuel and vegetation characteristics can be used strategically to plan fuel treatment and vegetation management projects across large landscapes. Maps can be translated into FCCS fuelbeds. Maps can be linked to stand (e.g., Forest Vegetation Simulator [FVS]) and landscape simulators to project future vegetation conditions under alternative treatment scenarios. Maps also can be linked to models of fire behavior and fire effects. Because the maps represent total vegetation conditions, they can be used in integrated analyses of multiple resources (e.g., effects of proposed fuel treatments on wildlife habitat).
Description	A method for vegetation mapping that integrates ground data from regional grids of field plots with satellite imagery and other spatial data by using multivariate gradient modeling and imputation.
Appropriate spatial scale	Very large scale (regional)
Analyst requirement	Requires a high level of analytical skills to apply this mapping method to a particular region. Requires knowledge of multivariate ordination concepts and methods (CANOCO or PCORD statistical software), spatial analysis skills (particularly ArcInfo and ArcMap), and knowledge of relational and spatial database management.
Data inputs	Requires the following: √ Statistical model developed with canonical correspondence analysis or redundancy analysis by using CANOCO or PCORD software. √ Field plot data that sample the range of vegetation variability in the area to be mapped, with plots being georegistered. Only those vegetation attributes measured on the plots, or that can be derived from field measurements, can be mapped. In other words, if fuels

	are to be mapped, fuel variables must be available for the plots. √ Spatial data layers for the area to be mapped for variables that are correlated with the vegetation elements to be mapped (e.g., measures of climate, topography, disturbance history, satellite imagery, soils).
Outputs	A map with each pixel or grid cell is assigned a single (nearest-neighbor) field plot, including all of the vegetation attributes measured on the plot. Maps can then be generated for any of these attributes, which are represented as continuous variables. Variables derived or modeled from the basic field-measured data also can be mapped, such as crown bulk density or fuelbeds from FCCS.
Linkage to other models/tools	Maps can translate into FCCS. The maps can be linked to stand (e.g., FVS) and landscape simulators to project future vegetation and fuel conditions. Maps also can be linked to models of fire behavior and fire effects (e.g., FlamMap, FARSITE). Because the maps represent total vegetation conditions, they can be used in integrated analyses of multiple resources (e.g., effects of proposed fuel treatments on wildlife habitat).
Developers (partners)	Forest Service Pacific Northwest Research Station (California Department of Forestry; Tom Leuschen [private consultant])
Current status	A beta version of the software is available by contacting Matt Gregory (matt.gregory@oregonstate.edu).
Training availability	No formal training is available or planned. Collaborative work with individuals or groups interested in using the GNN mapping method is possible.
Technical documentation	Ohmann, J.L.; Gregory, M.J. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest neighbor imputation in coastal Oregon, USA. Canadian Journal of Forest Research. 32: 725-741.

	Wimberly, M.C.; Ohman, J.L.; Pierce, K.B., Jr.; Gregory, M.J.; Fried, J.S. 2003. A multivariate approach to mapping forest vegetation and fuels using GIS databases, satellite imagery, and forest inventory plots. In: Proceedings of the second international Wildland Fire Ecology and Fire Management Congress. Boston, MA: American Meteorological Society. http://ams.confex.com/ams/FIRE2003/techprogram/paper_65758.htm (25 July 2006)
Contact	Janet Ohmann USDA Forest Service (541) 750-7487 johmann@fs.fed.us
Additional information	None.

Gradient Nearest Neighbor (GNN) Vegetation and Fuel Maps, Including Metadata and Accuracy Assessment

Application for fuel treatment	Maps of fuel and vegetation characteristics can be used strategically to plan fuel treatment and vegetation management projects across large landscapes. Maps can translate into FCCS fuelbeds. Maps can be linked to stand (e.g., Forest Vegetation Simulator [FVS]) and landscape simulators to project future vegetation conditions. Maps also can be linked to models of fire behavior and fire effects. Because the maps represent total vegetation conditions, they can be used in integrated analyses of multiple resources (e.g., effects of proposed fuel treatments on wildlife habitat).
Description	Digital maps of vegetation and fuel developed with the GNN method. Maps currently are available for coastal Oregon, eastern Washington, and the Sierra Nevada mountains.
Appropriate spatial scale	Maps are developed at a very large scale (region), but can be used at the scale of a 5th-field HUC.
Analyst requirement	A resource specialist or local GIS specialist can run the model or tool locally with minimal changes needed for local situations. Requires knowledge of image viewing and analysis software such as ArcMap. Conducting further analysis and summary of the vegetation and fuels data may require more advanced skills in grid-based analysis and database management.
Data inputs	Geospatial data.
Outputs	Digital maps of vegetation and fuel developed with the GNN method. Existing maps for coastal Oregon and eastern Washington are 30-meter (100-foot) resolution rasters (grid-based maps). Each pixel or grid cell in the map is assigned a field plot and all of the vegetation and fuel variables measured on the plot or that can be derived or modeled from the field measurements. Maps can be developed for any of these variables, which are

	represented as individual variables. New classification or summary variables also can be developed and mapped by the user to meet their particular objectives.
Linkage to other models/tools	Maps can be translated into FCCS fuelbeds. Maps can be linked to stand (e.g., FVS) and landscape simulators to project future vegetation and fuel conditions. The maps also can be linked to models of fire behavior and fire effects (e.g., FlamMap, FARSITE). Because the maps represent total vegetation conditions, they can be used in integrated analyses of multiple resources (e.g., effects of proposed fuel treatments on wildlife habitat).
Developers (partners)	Forest Service Pacific Northwest Research Station (California Department of Forestry, Oregon State University, University of Georgia, Tom Leuschen [private consultant])
Current status	Maps currently are available for coastal Oregon, eastern Washington, and Sierra Nevada.
Training availability	No formal training is available or planned. Collaborative work with individuals or groups interested in using the GNN maps is possible.
Technical documentation	Ohmann, J.L.; Gregory, M.J. 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest neighbor imputation in coastal Oregon, USA. Canadian Journal of Forest Research. 32: 725-741.
	Wimberly, M.C.; Ohman, J.L.; Pierce, K.B., Jr.; Gregory, M.J.; Fried, J.S. 2003. A multivariate approach to mapping forest vegetation and fuels using GIS databases, satellite imagery, and forest inventory plots. In: Proceedings of the second international Wildland Fire Ecology and Fire Management Congress. Boston, MA: American Meteorological Society. http://ams.confex.com/ams/FIRE2003/techprogram/paper_65758.htm (25 July 2006).

Contact	Janet Ohmann 3200 SW Jefferson Way Corvallis, OR 97331 (541) 750-7487 johmann@fs.fed.us
Additional information	None.

Guide to Fuel Treatments in Dry Forests of the Western United States: Assessing Forest Structure and Fire Hazard

Application for fuel treatment	Can be used to assess alternatives for NEPA analysis and other timber stand-level applications relative to thinning and surface fuel treatments. Can also be used for long-term scheduling of fuel treatments. Ideally users can reference fuel-treatment alternatives in the publication, then run their own FFE-FVS simulations to examine alternatives specific to their location.
Description	A guidebook and CD with quantitative guidelines and visualizations for how alternative silvicultural prescriptions and surface fuel treatments affect forest structure, fuels, and potential fire behavior. Cases are displayed for 25 representative forest stands from dry forests throughout the Western United States. FFE-FVS is used to calculate the effects of five thinning alternatives and three surface-fuel treatment alternatives on a large number of stand structure, fuel, and potential fire behavior metrics.
Appropriate spatial scale	Project/stand scale, but can be aggregated to larger spatial scales.
Analyst requirement	Resource specialist can use the guidebook in hardcopy or from the Web, and can apply to local situations.
Data inputs	Knowledge of local forest stand and fuel conditions.
Outputs	Changes over time, portrayed as: √ Visualizations √ Forest stand attributes √ Fuelbed properties
Linkage to other	Uses FFE-FVS, EnVision, the Landscape Management System (LMS), and potentially FCCS to derive outputs presented in guidebook. The guidebook is part of a set of tools online at http://forest.moscowfsl.wsu.edu/fuels.

Developers (partners)	Forest Service Pacific Northwest Research Station (Forest Service Fire and Aviation Management Staff [Washington Office], Forest Service Rocky Mountain Research Station, University of Washington)
Current status	Available at http://forest.moscowfsl.wsu.edu/fuels.
Training availability	Training generally is unnecessary unless users want to run their own FFE-FVS simulations. Developers are available for consultation.
Technical documentation	Johnson, M.C.; Peterson, D.L.; Raymond, C.L. 2006. [In press]. Guide to fuel treatments in dry forests of the Western United States: Assessing forest structure and fire hazard. Gen. Tech. Rep. PNW-GTR-686. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
Contact	Morris Johnson USDA Forest Service (206) 732-7852 mcjohnson@fs.fed.us or David L. Peterson USDA Forest Service (206) 732-7812 peterson@fs.fed.us
Additional information	None.

Harvest Cost and Revenue Estimator (HCR Estimator)

Application for fuel treatment	Provides detailed cost estimates for fuel treatment projects and financial return given available biomass and solid wood products from ponderosa pine within the region.
Description	The HCR Estimator is designed for ponderosa pine and calculates detailed harvest costs for fuel treatments, predicts volumes of material used by diameter class, and estimates financial return for raw material markets to be used for project appraisal. The model provides information to forest planners to conduct project appraisal, set minimum contract bid rates, and assess stumpage value of material removed. Contractors can use the model to estimate operation and maintenance costs of equipment and generate detailed cost estimates for project bidding. Community partners can use the model to assess project feasibility and assist project design and community development.
Appropriate spatial scale	Stand/project scale.
Analyst requirement	Resource specialist or local GIS specialist can run the model or tool locally with minimal changes needed for local situation.
Data inputs	Base resource data readily available at the regional or local scale, and some specialized data in the form of harvesting equipment used.
Outputs	The HCR Estimator provides a: √ Log calculator that calculates log types (size and volume) and numbers as a function of cut trees and market specifications. √ Cost estimator that determines harvesting, handling, and transportation costs from production rate relationships, equipment and labor costs, trucking information, and cut tree and log data.

	√ Revenue predictor that estimates financial return and economic thresholds based on the log calculator and user-defined raw material market specifications for wood-plastic composites, heating and electricity, biochemicals, engineered lumber, and other value-added products.
Linkage to other models/tools	Potential to integrate with FVS.
Developers (partners)	Forest Service Pacific Northwest Research Station (Forest Service Southern Research Station, Rocky Mountain Research Station, and Southwestern Region; Northern Arizona University)
Current status	A beta version of the model is being tested, with regional trainings to be conducted in 2006. More information at http://www.fs.fed.us/pnw/sev/esp/ESP-JFSP.htm.
Training availability	Workshops may be available up on request.
Technical documentation	Barbour, R.J.; Parry, D.L. 2001. Log and lumber grades as indicators of wood quality in 20- to 100-year-old Douglas-fir trees from thinned and unthinned stands. Gen. Tech. Rep. PNW-GTR-510. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 22 p.
	Parry, D.L.; Filip, G.M.; Willits, S.A.; Parks, C.G. 1996. Lumber recovery and deterioration of beetle-killed Douglas-fir and grand fir in the Blue Mountains of eastern Oregon. Gen. Tech. Rep. PNW-GTR-376. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 24 p.
	Stevens, J.A.; Barbour, R.J. 2000. Managing the stands of the future based on the lessons of the past: estimating Western timber species product recovery by using historical data. Res. Note PNW-RN-528. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 11 p.

Barbour, R.J.; Fight, R.D.; Christensen, G.; Pinjuv, G.L.; Venkatarao, N. 2001. Assessing the need, costs, and potential benefits of prescribed fire and mechanical treatments to reduce fire hazard in Montana and New Mexico. Report to the Joint Fire Science Program. http://www.fs.fed.us/pnw/woodquality/JLMFinal_report_dft5.PDF (4 August 2006).

Contact

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Additional information

The HCR Estimator is a Windows -based, public-domain engineering software program for evaluating stand-scale economic thresholds for harvesting small-diameter ponderosa pine. It depends on an internal log calculator to determine merchantable volumes and log potential as a function of stand data and market conditions. Merchantable tree definitions and log volumes are calculated directly from tree data and log specifications. Predictions of followup treatment activities are linked directly to log potential, better reflecting true stand conditions and revenue potential.

The model has three parts with required user-defined inputs (defaults available for different levels of users):

√ Log calculator–Calculates the size and volume of logs generated from fuel reduction and forest restoration treatments as a function of cut trees and market specifications.

√ Cost estimator–Determines harvesting and transportation costs from production rate relationships, equipment and labor costs, trucking information, and cut tree and log data.

√ Revenue predictor–Estimates net financial return of biomass and logs removed from forest treatments and sold to primary and secondary manufacturing businesses.

Financial returns are based on existing market specifications in the region. For example, logs with a 4-inch top (outside bark) that are 16 feet long used to make wood pallets have a different market value than logs with a 6-inch top (outside bark) that are 24 feet long used for dimensional lumber.

The HCR Estimator optimizes economic return by determining which harvested trees generate logs that meet user-defined markets. For example, if the greatest return is from logs used for dimensional lumber, the model will determine the maximum number of logs that meet market specifications for that end use. Remaining logs and biomass are then allocated according to the next highest raw material market value. Different markets presumably have different costs associated with harvesting requirements and transportation distances to manufacturing facilities. These costs, along with possible offsets from service contracts, are compared against total financial return to calculate potential net profit. This information can be used to identify per-acre cost thresholds, appraise service contract bid rates, and assess stumpage values for small-diameter timber and biomass.

Integrated Forest Resource Management System (INFORMS)

Application for fuel treatment	INFORMS currently is used mostly to support the NEPA process, particularly for fuel treatment projects. The application uses data from the FSVeg database grown forward by using the Forest Vegetation Simulator (FVS) including the Fire and Fuels Extension (FFE-FVS) for the current condition and each decade into the future up to 40 years. It is possible to create as many treatment alternatives as desired. These can be portrayed for the same growth periods to compare differences between treatment and no treatment and between alternative treatments.
Description	INFORMS is a software system designed to facilitate planning activities in the USDA Forest Service. It is designed specifically to help support project-scale (NEPA) and landscape-scale planning. However, some users may find INFORMS useful for other types of planning exercises. INFORMS is installed on the Forest Service computer network at certain sites.
Appropriate spatial scale	Small to medium
Analyst requirement	Low. Users define project information, manage the project team, execute tools, build alternatives, etc.
Data inputs	√ Choice of GIS data sets already located in INFORMS database √ Choice of which analytical tools to integrate
Outputs	INFORMS can be used for several types of land management planning. In the fire and fuel analysis packages, the outputs are: √ Maps of burn intensity √ FARSITE-ready data
Linkage to other models/tools	ArcView, FVS, FARSITE, MSN, SVS

Developers (partners)	In addition to many field-level partners, the INFORMS development team is coordinating closely with several other development teams. These groups include FSVEG database, FVS (i.e., the Forest Management Service Center and the Intermountain Research Station), and Decision Protocol development teams.
Current status	Currently available on the Forest Service computer network, and being developed for use by others who use Linux.
Training availability	Unknown.
Technical documentation	User's Guide available at http://www.fs.fed.us/informs/Usersguide/informs_help.html
Contact	Eric Twombly USDA Forest Service (541) 742-6707 etwombly@fs.fed.us
Additional information	INFORMS is not available to other agencies at present.

LANDFIRE

Application for fuel treatment	Provides maps of vegetation, fire, and fuel characteristics at scales fine enough to assist in prioritizing and planning specific hazardous fuel reduction and ecosystem restoration projects.
Description	LANDFIRE is a 5-year, multipartner wildland fire, ecosystem, and wildland fuel mapping project. The consistent and comprehensive nature of LANDFIRE methods ensures that data will be nationally relevant, and the 30-meter (100-foot) grid resolution assures that data can be locally applicable.
Appropriate spatial scale	Medium to large. Available nationally at 30-meter (100-foot) resolution.
Analyst requirement	Low to moderate
Data inputs	Geographic area for which you wish to view a map.
Outputs	√ Prototype products consisting of various databases, computer models, and geospatial data developed for the LANDFIRE prototype project to demonstrate that the methods and protocols could be applied nationwide. √ Rapid assessment products (maps and models of potential natural vegetation groups, reference fire regimes, and fire regime condition class for the conterminous United States) that can be used for national- to regional-scale strategic planning, broad ecological assessments, and resource allocation. √ National assessment products, a set of 30+ digital maps of vegetation composition and structure; wildland fuel (crown and surface); and current departure from simulated historical vegetation conditions.
Linkage to other models/tools	National—FARSITE, FOFEM, Consume Prototype—WXFIRE, DAYMET, Biome-BGC, LANDSUM. Each potential natural vegetation group was modeled quantitatively in the Vegetation Dynamics Development Tool (VDDT) software.

Developers (partners)	USDA Forest Service, Rocky Mountain Research Station Missoula Fire Sciences Laboratory; USGS National Center for Earth Resources Observation and Science; (USDA Forest Service Remote Sensing and Applications Center and Pacific Northwest Research Station; USDI Office of Wildland Fire Coordination, Geological Survey, Bureau of Land Management, National Park Service, Bureau of Indian Affairs, and Fish and Wildlife Service; Federal Emergency Management Agency; Western Governors' Association; The Nature Conservancy; Student Conservation Association; Nature Serve; Systems for Environmental Management; Science Application International Cooperation; National Association of State Foresters; and National Association of County Officials)
Current status	LANDFIRE products will be completed by zone through 2009. http://www.landfire.gov/schedule_map.php.
Training availability	From December 2005 through 2009, the National Interagency Fuels Technology Team (NIFTT) will travel around the United States—starting in the West—to conduct technology transfer workshops (FOR 438) through which participants will learn how to use LANDFIRE data in their local areas. Specifically, participants will learn about and be trained to use the tools that facilitate the local application of LANDFIRE data to support the prioritization and planning of specific hazardous fuel reduction and ecosystem restoration projects. For more information, visit http://www.landfire.gov/TT_TTW.html.
Technical documentation	Keane, R.E.; Rollins, M.G.; McNicoll, C.H.; Parsons, R.A. 2002. Integrating ecosystem sampling, gradient modeling, remote sensing, and ecosystem simulation to create spatially explicit landscape inventories. RMRS-GTR-92. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 61 p.

	Schmidt, K.M.; Menakis, J.P.; Hardy, C.C.; Hann, W.J.; Bunnell, D.L. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. Gen. Tech. Rep. RMRS-GTR-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 41 p. + CD-ROM.
Contact	helpdesk@landfire.gov
Additional information	These types of geospatial data provide fire and land managers with needed information to identify the amount and location of lands with wildland fuel buildup and facilitate the prioritization and implementation of landscape fuel treatments. Moreover, these data may be used during specific wildland fire incidents to increase firefighter safety, pre-position resources, and evaluate fire behavior under a variety of weather conditions.

LANDIS and LANDIS-II

Application for fuel treatment	LANDIS enables a user to simulate multiple interacting disturbance processes (including fuel treatments and timber management) and forest succession. Replicate simulations can be used to produce a fire probability map, which can be compared for alternative fuel treatment or landscape management strategies. Because interactions among multiple processes are accounted for, unintended effects of fuel treatments can be avoided.
Description	LANDIS was designed to model forest succession, disturbance (including fire, wind, harvesting, fuel treatments, insects, climate change), and seed dispersal across large landscapes. LANDIS tracks age and spatial distribution of individual species and has a flexible spatial resolution. LANDIS-II also tracks living and dead biomass of species cohorts (using PnET-II).
Appropriate spatial scale	1000 to >1 million ha (2,500 to >2,500,000 acres)
Analyst requirement	Familiarity with ecological modeling, GIS, and forest ecology is desirable.
Data inputs	LANDIS requires raster GIS layers of tree species and age cohort information, ecological units (land type), and management areas (when spatially distributing varied harvest or fuel treatment activities). Required parameters include life history attributes for each tree species, disturbance regime parameters, and harvest and fuel treatment parameters. A wide range of optional processes provide a high degree of flexibility in the questions that may be addressed, as well as the input data required to address those questions.
Outputs	The primary outputs of LANDIS are maps that represent the state of the landscape at a given time step. The user specifies what maps are to be output and at what interval. Typical outputs are forest type or age class, relative dominance of species or age classes, location of

	disturbances (at a time step or cumulative), intensity of disturbances, fuel load, and (from LANDIS-II) species biomass.
Linkage to other models/tools	Spatial pattern of output maps is readily analyzed by using APACK, IAN and FRAGSTATS. The fire module has the optional capability to emulate FARSITE behavior. LINKAGES has been used to estimate establishment coefficients for tree species. LANDIS-II incorporates PnET-II to model living and dead biomass.
Developers (partners)	Forest Service Northern Research Station, University of Wisconsin-Madison, University of Missouri-Columbia.
Current status	LANDIS 4.0 was released in April 2005. LANDIS-II was released in October 2005, but the full complement of disturbance modules will not be completed until fall of 2006.
Training availability	By request.
Technical documentation	He, H.S.; Li, W.; Sturtevant, B.R.; Yang, J.; Shang, B.Z.; Gustafson, E.J.; Mladenoff, B.J. 2005. LANDIS 4.0 users guide. LANDIS: a spatially explicit model of forest landscape disturbance, management, and succession. Gen. Tech. Rep. GTR-NC-263. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 93 p.
Contact	Eric Gustafson USDA Forest Service (715) 362-1152 egustafson@fs.fed.us
Additional information	The appropriate temporal scale for LANDIS applications is 50 to 1,000 years. LANDIS has been applied in ecosystems as varied as sub-boreal (upper Midwest), boreal (Canada, Scandinavia), alpine (Switzerland), central hardwoods (Midwest), loblolly pine (Georgia), California chaparral, and forests of China.

Landscape Simulator

Application for fuel treatment	The model is designed to examine potential interactions between terrestrial processes of sediment and wood production and aquatic processes of habitat creation and maintenance, including the stochastic elements of fire and storm-driven sediment fluxes. Potential uses include examination of consequences of changes in fire regime.
Description	Simulation of landscape elements that drive channel dynamics, including fires, storms, landslides, woody debris recruitment, and sediment routing. Currently applied only for estimated natural conditions, but management scenarios and effects of altered fire and soil erosion regimes will be addressed in future work.
Appropriate spatial scale	The model runs at the resolution of available digital elevation data (e.g., 10 meters [33 feet]), but results can be integrated and displayed over larger scales. The model has been used on a 200 square kilometer (80 square mile) portion of the Tilton River basin in Washington, and extended to a 1300 square kilometer (500 square mile) portion of the Cowlitz River basin in Washington.
Analyst requirement	A user interface has not yet been developed. The model requires development of a variety of data sets (e.g., characterization of the fire regime, climate, soil production), requiring a high level of analysis.
Data inputs	The processes simulated by the model must all be characterized, including fire regime (e.g., ignition probability, topographic and vegetation controls on fire size and location), storm magnitude (e.g., intensity, duration), spatially distributed patterns of forest growth and mortality, soil production and transport, mass wasting, attrition rates for fluvially transported sediment. Parameterization is done primarily by using probability distribution functions, which must be developed regionally.

Outputs	Production and flux of sediment and woody debris pixel by pixel over a DEM-representation of a watershed. Outputs include volume of sediment and wood within pixel-length channel reaches for each year of the simulation.
Linkage to other models/tools	Potential linkage with the CLAMS vegetation models. Ongoing development will couple the landscape simulation model with a model of fish productivity to examine potential consequences to fish populations of dynamic physical elements in aquatic ecosystems.
Developers (partners)	Forest Service Pacific Northwest Research Station (Earth Systems, NOAA Fisheries)
Current status	Available on CD-ROM; user interface not yet developed.
Training availability	None.
Technical documentation	U.S. Deparment of Agriculture, Forest Service. 2003. Landscape dynamics and forest management. [CD-ROM] Gen. Tech. Rep. RMRS-GTR-101CD. Fort Collins, CO: Rocky Mountain Research Station.
Contact	Daniel Miller Earth Systems Institute (206) 633-1792 danmiller@earthsystems.net
Additional information	None.

My Fuel Treatment Planner (MyFTP)

Application for fuel treatment	Intended for the early stages of project planning and for stimulating discussion within interdisciplinary teams about what is and is not feasible given available budgets. It is particularly useful for NEPA analyses and similar documents for which alternative treatments are examined.
Description	MyFTP calculates and presents cost and revenue information on fuel treatment scenarios. The target audience includes district and forest staffs and their counterparts in the Bureau of Land Management who often have little background in timber management or sales. Those familiar with timber sale planning might find the tool a useful first step in the planning process. It is designed to deal with a limited set of scenarios, and default values are presented for many of the data items.
Appropriate spatial scale	MyFTP is intended for use at the project or stand scale but it could also be used for larger landscapes to analyze typical or average conditions.
Analyst requirement	A low level of analyst support is required.
Data inputs	MyFTP requires: √ Cut tree list (from a stand exam, or imported from FVS). √ Product (log and chip) prices, which are available from Forest Service regional sources and BLM state offices. √ Objective for using cut trees–logs, chips, unutilized; slope, unit size, skidding/yarding distance, pretreatment fuel load, minimum top for utilized trees, log prices, and a few other optional items provided by the analyst
Outputs	The analyst creates a scenario, then visits the various calculators within the model that are relevant to the chosen scenario to complete the analysis of: √ Harvest cost √ Hauling cost √ Mastication cost

	√ Prescribed fire √ Economic impacts on local communities
Linkage to other models/tools	MyFTP imports data from FVS. My FTP is part of a set of tools online at http://forest.moscowfsl.wsu.edu/fuels.
Developers (partners)	Forest Service Pacific Northwest Research Station (Forest Service Fire and Aviation Management Staff [Washington Office], Southern Research Station, Rocky Mountain Research Station)
Current status	MyFTP is available from the developers and online at http://www.fs.fed.us/pnw/data/myftp/myftp_home.htm.
Training availability	Training is available to interested parties through a Forest Service enterprise team.
Technical documentation	Biesecker, R.L.; Fight, R.D. 2006. My fuel treatment planner: a users guide. Gen. Tech. Rep. PNW-GTR-663. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 31 p.
Contacts	Dennis Dykstra USDA Forest Service (503) 808-3132 ddykstra@fs.fed.us or Stephanie Rebain USDA Forest Service (970) 295-5793 sarebain@fs.fed.us
Additional information	Although MyFTP allows for comparison of alternatives and some co-imaging of scenarios, it is not intended to provide a site-specific appraisal for a project. MyFTP was designed to address treatment costs, potential for offsetting costs with product utilization, the effect of treatment on surface fuel loads, and the economic

impact at the time of fuel treatment. Longer term economic impacts could occur if fuel treatment affects other forest uses such as recreation. Current research on the effect of thinning and prescribed fire treatments on recreation and other forest uses is too limited to provide the basis for modeling these effects.

NEXUS

Application for fuel treatment	The model can be used to estimate surface, transition, and crown fire behavior, generate site-specific indices of torching and crown fire potential, and to evaluate alternative treatments for reducing risk of crown fire.
Description	The spreadsheet is used to assess crown fire potential in up to six stands at a time.
Appropriate spatial scale	Primarily stand scale, but can be used to assess small watersheds (e.g., 6^{th}-field HUC).
Analyst requirement	Moderate level of analyst skill is needed to provide certain inputs. User must be able to obtain an estimate of canopy characteristics, such as canopy bulk density and canopy fuel loading.
Data inputs	√ Fuel model √ Live and dead fuel moistures √ Canopy bulk density √ Canopy foliar moisture √ Canopy base height √ Canopy fuel load √ Slope steepness √ 20-foot windspeed √ Wind direction from uphill √ Wind reduction factor √ Multipliers for surface and crown fire rates of spread √ Surface loading, depth, fire intensity √ Temperature √ Elapsed time √ Map scale
Outputs	Type of fire, crown fraction burned, surface fire behavior, scorch height, fire length-to-width ratio, perimeter growth rate, fire area, spread distance, map spread distance, potential crown-fire rate of spread, torching index, crowning index, surfacing index, and critical parameters for crown fire initiation, active spread, and cessation.
Linkage to other models/tools	None.
Developers (partners)	Forest Service Rocky Mountain Research Station (Systems for Environmental Management)

Current status	Spreadsheet is fully functional. Available at http://www.fire.org.
Training availability	None.
Technical documentation	Scott, J.H.; Reinhardt, E.D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 59 p. http://www.fs.fed.us/rm/pubs/rmrs_rp29.pdf
Contact	Joe Scott Systems for Environmental Management (406) 329-4837 joe.scott@montana.com
Additional information	Crown fire results differ from the results provided through CrownMass and FFE-FVS, and possibly BehavePlus. CrownMass has been used to generate canopy characteristics for use in NEXUS. A separate help file is included in the download package.

Optimizing Fuel Solutions and Ecological Values in Landscapes (FUELSOLVE)

Application for fuel treatment	Planning fuel treatment and vegetation management projects and forest planning efforts (e.g., scenario planning, prioritization, describing desired future conditions, fire effects modeling).
Description	Intended to optimize amount and pattern of fuel treatments and the persistence of ecological features from wildfire, such as late-successional forest. It uses current condition in a short-term simulation period (i.e., does not model forest growth). Assists the design and evaluation of "firesafe" landscapes based on fuel, fire, and ecological criteria. A separate landscape condition assessment tool, NOCLAMMS, will be integrated as a pre-optimization step to provide an ecological evaluation of landscape deviation from baseline historical conditions based on Interior Columbia River Basin Management Project midscale analysis.
Appropriate spatial scale	Landscapes of less than 50,000 acres. Designed for watershed-scale analysis. Ranger district/resource area project-level application.
Analyst requirement	Requires a midlevel analyst or GIS specialist to run the model or tool or make it usable for local situations.
Data inputs	√ Ignition data √ Map of zones with ignition probability used to "start" wildfires, and severe fire weather data √ Identification of untreated stands √ FARSITE fire model stand data for elevation, aspect, slope, fuel model, stand height, height to live canopy, canopy bulk density, etc. √ Treatment details of stand structure modification (e.g. silvicultural practices, prescribed burning, spatial patterns of fuel treatments ([random, adjacent to protected stands, etc.])

	√ Evaluation criteria (e.g., simulated wildfire size, intensity, effects, late-seral forest amount, and connectivity). Other fire or ecosystem values can be added in later development).
Outputs	√ Maps of options and wildfire and ecological evaluations √ Text data on evaluation criteria for treatment combinations
Linkage to other	FARSITE (abbreviated version), FlamMap, and FCCS fuelbeds and fire potentials. A grand fir series model for NOCLAMMS is available, but development of a dry forest (ponderosa pine, Douglas-fir) version is needed.
Developers (partners)	Forest Service Pacific Northwest Research Station (University of Washington)
Current status	Development in progress, with final prototype available in 2006.
Training availability	Training will be available, pending completion of prototype in 2006.
Technical documentation	None.
Contact	John Lehmkuhl USDA Forest Service (509) 664-1737 jlehmkuhl@fs.fed.us
Additional information	Goal is to allow fuel planners, fire staff, biologists, regulators, and the public to (1) plan and evaluate the area and spatial pattern of fuel treatment alternatives, potential wildfire futures, and ecological effects on key protected resources (e.g., spotted owl habitat or locations) and (2) identify preferred alternatives to maximize fuel treatments and protect resources based on best available science.

Simulating Patterns and Processes at Landscape Scales (SIMPPLLE)

Application for fuel treatment	SIMPPLLE enables a user to generate probability maps of disturbance processes and vegetation attributes from multiple stochastic simulations. These results can be used to assign priorities for fuel treatments across landscapes. Changes in the occurrence and intensity of wildfire and other disturbance processes can be evaluated with alternatives of temporal and spatial assignment of fuel treatments.
Description	SIMPPLLE was developed as a management tool to provide resource analysts and managers with the ability to create spatially explicit, stochastic simulations of vegetation changes caused by disturbance processes. Multiple simulations are used to identify not just average future conditions, but a range of conditions for both plant communities and processes that can be expected for specific landscapes. Both short- and long-term simulations can be used to analyze treatment scenarios for their impact on disturbance processes and the attainment of desired future conditions. SIMPPLLE is a Java application and will run on any platform that has a Java Virtual Machine version 1.4.1 or higher.
Appropriate spatial scale	SIMPPLLE can be used across all spatial scales from a few hundred acres to millions of acres.
Analyst requirement	SIMPPLLE is easy to run. Changing system knowledge database requires more effort to learn the system, but changes can be made through the user interface. Developing all the system knowledge data for a new geographic area can be partially accomplished by a user and requires some system developer involvement.
Data inputs	For each landscape, SIMPPLLE requires a GIS layer of vegetation (either grid or polygons) that provides dominant cover type, size-class and structure, and density; a GIS layer of ecological stratifications; and a digital

elevation model or an elevation field within the vegetation layer. Optional inputs are GIS layers of insect and disease activity; fire events and treatments to provide each plant community with a history; and GIS layers to identify each plant community by ownership, wildland-urban interface, land use allocation, drainage, etc. that can be used to schedule treatments and summarize output. Areas that have a geographic zone developed in SIMPPLLE have attributes for both the vegetation and ecological stratification already defined.

Outputs

SIMPPLLE provides output for both individual vegetation units and the entire landscape. For individual units, the system provides the disturbance processes modeled, their occurrence probabilities, changes in vegetation state, and whether a process originated within a unit or spread to a unit. The acres for each vegetation attribute, disturbance process, and treatments are displayed by time step for the entire landscape. These results can be produced in a report, or the attributes for individual units can be mapped. Mapping can be done through either a customized ArcView project file or an ArcGIS extension that comes with the system.

Reports list the number of fire events by size class. For each fire event, its origin and the units to which it spreads are identified. Smoke emissions produced by wildfires and prescribed fires, and fire suppression costs, if fire suppression is used, are reported. For multiple simulations, the display for individual units includes the frequency for each unique value of species, size-class/size-structure, and density, and disturbance process. The time-step summaries for the entire landscape display an average and the high and low values from the multiple simulations. Excel spreadsheets with macros are available that provide basic statistics for the output and line graphs, provide for statistical testing of output between alternatives, and combine data for use in

	a diversity matrix. Interpretative reports can be selected for ecological restoration needs and for acres of potential habitat for wildlife species.
Linkage to other models/tools	The system knowledge in SIMPPLLE can be developed from fine-scale models on sample plant communities and smaller landscapes. FVS with its extensions can be used to develop the time and next states within SIMPPLLE pathways. FARSITE can be used to improve the fire spread logic within the system. SIMPPLLE can be used with optimization and scheduling systems of MAGIS and SPECTRUM. SIMPPLLE can provide input that can be used by these systems in their scheduling algorithms and by testing the treatment schedules developed by them. If a grid is used to represent the vegetation, the output can be used with FRAGSTATS. Change in vegetation attributes can be used as input into the U.S. Geological Survey Precipitation Runoff Modeling System (PRMS).
Developers (partners)	USDA Forest Service Rocky Mountain Research Station, (USDA Forest Service Pacific Southwest Research Station and Northern Region; Joint Fire Science Program; National Fire Plan; USDI Bureau of Land Management)
Current status	SIMPPLLE 2.2 and a draft user's guide were released in 2004. Geographic areas available are the Forest Service Northern Region (applicable to any ownership within the area), Sierra Nevada, and southern California. SIMPPLLE 2.3 is available for downloading, although the user manual has not been updated for it. Additional geographic areas that are operational are the Gila National Forest, south-central Alaska, southwest Utah, and the Colorado Front Range. Each geographic area has a sample landscape within SIMPPLLE that can be used as a training aid.

Training availability	Versions of SIMPPLLE and its draft users guide with training exercises can be downloaded at http://www.fs.fed.us/rm/missoula/4151/SIMPPLLE.
Technical documentation	Chew, J.D.; Stalling, C; Moeller, K. 2004. Integrating knowledge for simulating vegetation change at landscape scales. Western Journal of Applied Forestry. 19: 102-108.
Contact	Jim Chew USDA Forest Service Missoula, MT 59807 (406) 542-4171 jchew@fs.fed.us
Additional information	None.

Smoke Impact Spreadsheet (SIS)

Application for fuel treatment	SIS evaluates smoke impacts of different wildland burning scenarios for all vegetation types in the United States
Description	SIS is a planning model for calculating particulate matter emissions and concentrations downwind of wildland fires. It conservatively predicts downwind particulate matter concentrations for comparison with appropriate federal or state air quality standards. It replaces SASEM.
Appropriate spatial scale	Small
Analys requirement	Low
Data inputs	√ Burn name √ Burn type √ Burn acres √ FOFEM fuel type √ Fuel loading by size √ Terrain information √ Pile data √ Broadcast burn data √ Location √ Windspeed and direction √ Maximum temperature √ Pasquill-Gifford stability class
Outputs	√ Prediction of 1-hour and 24-hour average particulate matter concentrations
Linkage to other models/tools	FOFEM, Consume, CALPUFF (replaces SASEM)
Developers (partners)	Forest Service, Northern Region (Air Sciences Inc.)
Current status	Available.
Training availability	Unknown.
Technical documentation	User's manual available at http://www.airsci.com/SISmodel/SIS_Users_Manual-6.17.03.pdf.
Contact	Trent Wickman USDA Forest Service (218) 626-4372 twickman@fs.fed.us
Additional information	None.

Stereo Photo Series for Quantifying Natural Fuels

Application for fuel treatment	Straightforward determinations of fuel quantities and stand conditions for predicting fuel consumption, smoke production, fire behavior, and effects of wildfires and prescribed fires.
Description	Natural fuels photo series are designed to help land managers appraise fuel and vegetation conditions in natural settings. It currently includes 11 volumes representing various regions of the United States and one volume from Brazil. There are 1 to 4 series in each volume, each having 4 to 17 sites. Sites include standard, wide-angle, and stereo-pair photographs. Each group of photos includes inventory data summarizing vegetation composition, structure, and loading; woody material loading; density by size class, forest floor depth, and loading; and various site characteristics.
Appropriate spatial scale	Small to medium, depending on the heterogeneity of the landscape.
Analys requirement	Low
Data inputs	Knowledge of forest type, biomass, and structure of fuelbed components sufficient to choose a best match from a series of single photos and stereo photo pairs.
Outputs	Inventory data summarizing: √ Vegetation composition, structure, and loading √ Woody material loading √ Density by size class √ Forest floor depth and loading √ Various site characteristics
Linkage to other models/tools	Data from the photo series were used to construct many of the standard fuelbeds within the Fuel Characteristic Classification System (FCCS). Fuels data determined by the photo series can be input into fire and fuels programs such as Consume 3.0, FOFEM, and FEPS. It can also be used to customize FCCS fuelbeds.

Developers (partners)	Forest Service Pacific Northwest Research Station (National Fire Plan; Joint Fire Science Program; U.S. Department of the Interior, Bureau of Land Management [Alaska Fire Service], U.S. Fish and Wildlife Service, and National Park Service; USDA Forest Service Pacific Northwest Region and Pacific Southwest Research Station; U.S. Agency for International Development Brazil Program; Department of Defense—Eglin Air Force Base [Natural Resources Branch], Pohakulo and Makua Training Areas; State of Hawaii, Department of Natural Resources [Division of Forestry and Wildlife]; University of Brasilia Department of Ecology).
Current status	Eleven volumes available, and six in progress. Detailed information on available series and ordering can be found at http://www.fs.fed.us/pnw/fera/.
Training availability	Tutorial is available at http://www.fs.fed.us/pnw/fera/outreach/tutorials.
Technical documentation	Ottmar, R.D.; Vihnanek, R.E.; Miranda, H.S.; Sato, M.N.; Andrade, S.M.A. 2004. Stereo photo series for quantifying biomass for the cerrado vegetation in central Brazil. Floresta. 34: 109-112. Ottmar, R.D.; Vihnanek, R.E.; Wright C.S. 2003. Stereo photo series for quantifying natural fuels in the Americas. [Abstract]. In: Kush, J.S., comp. Longleaf pine: a Southern legacy rising from the ashes, proceedings of the fourth Longleaf Alliance regional conference. Longleaf Alliance Report No. 6:123.
Contact	Roger Ottmar USDA Forest Service (206)732-7826 rottmar@fs.fed.us
Additional information	The photo series can be used to assess live and dead woody material and vegetation biomass, and stand characteristics across landscapes. Once an ecological

assessment has been completed, stand treatment options such as prescribed fire or harvesting can be planned and implemented to better achieve desired effects while minimizing negative impacts on other resources.

The photo series is useful in several branches of natural resource science and management. Inventory data such as these can be used as inputs for evaluating wildlife habitat, nutrient cycling, and microclimate. In addition, the photo series can be used to appraise carbon distribution in biomass and to link remotely sensed signatures to live and dead fuels on the ground.

Tool for Exploratory Landscape Scenario Analysis (TELSA)

Application for fuel treatment	TELSA can be used to examine changes in vegetation and fuel conditions given different management scenarios, natural disturbance regimes, and assumed long-term trends (e.g., warming climate). Spatial strategies for fuel treatments can be examined, but the model does not project actual fire weather and burning conditions. Fire contagion is a relatively simple process based on the susceptibility of adjacent polygons to fire. However, the model is useful for examining landscape vegetation, fuel, and fire trends given different management approaches.
Description	TELSA is a spatially explicit state and transition model that can be used to model the short- and long-term interactions of vegetation, management, and disturbance. Most analysts use it to depict vegetation as structure (e.g., grass/shrub, seedling, sapling, pole, etc.) and cover (e.g., dominant species group) classes connected by growth, succession, management activities, and natural disturbances.
Appropriate spatial scale	TELSA can be used at stand to watershed or larger scales through the appropriate choice of state classes (usually vegetation types). TELSA is limited by the maximum size of Microsoft Access97 databases (1 gigabyte), although the database is being converted to a newer version of Access, and maximum size limits will become 2 gigabytes or more. This limitation makes TELSA difficult to run on very large landscapes or where the number of simulated vegetation polygons exceeds 75,000 to 100,000.
Analyst requirement	TELSA requires thoughtful assembly and local expertise in vegetation types, disturbances, and management activities. VDDT models are used as the basis for TELSA, but additional expertise in GIS and Access database analysis is required.

Data inputs	TELSA models are generally built by an analyst, resource specialist, or planner using local expert opinion, existing data, and available literature. The process is facilitated by first building and testing VDDT models. GIS coverages of vegetation state classes, management allocations or zones, potential vegetation type groups, roads (optional), proposed management units (optional), and other attributes are either required or optional.
Outputs	√ Graphic and GIS (ArcGIS shapefiles and databases) displays of state class conditions, disturbances, management activities, and calculated or other assigned attributes over time. √ Time step-by-time step output of percentages and area of the landscape in vegetation state classes, management activities, and natural disturbances. Output can be easily imported to spreadsheets or databases for further analyses. Model runs of a few hundred years typically require several hours, and randomly chosen initial probability seeds can be run for statistical analysis.
Linkage to other	TELSA models feed directly from VDDT and can be used to examine the spatial implications of VDDT models. FVS and other simulation tools can be used to develop TELSA pathways and probabilities. Any other model or tool that uses vegetation state classes (e.g., GIS, FRAGSTATS, Bayesian Belief Network, INFORMS) can supply input to or use data from TELSA. This is straightforward when spreadsheets or databases are used for output.
Developers (partners)	Forest Service Pacific Northwest Research Station (ESSA Inc., Vancouver, British Columbia)
Current status	Available for research or educational use without charge at http://www.essa.com. Potential users should contact Diana Abraham of ESSA Technologies to discuss obtaining TELSA or for contracted support.

Training availability	Interested potential users should contact Diana Abraham of ESSA Technologies to discuss training sessions for TELSA.
Technical documentation	ESSA Technologies Ltd. 2005. TELSA—tool for exploratory landscape scenario analyses: user's guide version 3.3. Vancouver, BC. 236 p.
	ESSA Technologies Ltd. 2005. TELSA: tool for exploratory landscape scenario analyses, model description, version 3.3. Vancouver, BC. 50 p.
	Beukema, S.J.; Kurz, W.A.; Klenner, W.; Merzenich, J.; Arbaugh, M. 2003. Applying TELSA to assess alternative management scenarios. In: Arthaud, G.J.; Barrett, T.M., eds. Systems analysis in forest resources. Norwell, MA: Kluwer Academic Publishers. 145-154.
	Merzenich, J.; Kurz, W.A.; Beukema, S.J.; Arbaugh, M.; Schilling, S. 1999. Long-range modelling of stochastic disturbances and management treatments using VDDT and TELSA. In: Proceedings, Society of American Foresters 1999 national convention; SAF Publication 00-1. Bethesda, MD: Society of American Foresters. http://www.essa.com/downloads/vddt_telsa.pdf.
Contacts	Sarah Beukema or Don Robinson ESSA Technologies Ltd. (604) 733-2996 INCLUDEPICTURE sbeukema@essa.com or drobinson@essa.com
Additional information	Example map output for a 100-year run of a natural disturbance regime scenario in the upper Grande Ronde River basin area in Oregon. Extensive tabular and other graphic output is available.

Understory Response Model (URM)

Application for fuel treatment	The Understory Response Model will help managers predict the impact of specific fuel treatment on specific plant species, select between alternative fuel treatments, predict the impact of fuel treatment on threatened and endangered species (TES), and predict the location and magnitude of posttreatment weed response. This will aid managers in selecting management strategies to mitigate against potential negative effects of fuel treatments on understory plants.
Description	The Understory Response Model is a species-specific computer model that qualitatively predicts change in total species biomass for grasses, forbs, and shrubs after thinning, prescribed fire, or wildfire. The model examines the effect of fuel management on plant survivorship (the survival, growth, and colonial growth of plants present at the site before treatment) and reproduction (establishment and growth of plants from stored seeds and onsite and offsite colonization). It can be accessed online at http://forest.moscowfsl.wsu.edu/fuels/; a PC-based model is being developed as well.
Appropriate spatial scale	The model was designed to be used at the stand level.
Analyst requirement	There are no specific user requirements to run the model. However, local knowledge of the site and understory vegetation is needed for the model inputs.
Data inputs	√ Initial stand conditions (size of treatment area, starting canopy cover, average duff depth). √ Plant life history traits (lifespan, life form, shade tolerance, root location, bud location, vegetative reproduction, weediness, sprouting ability, preferred light levels, seed dispersal, seedbank, fire stimulated seeds, presence onsite or offsite). √ Thinning effects (canopy cover after thinning, mineral soil exposed by thinning, timing of thinning and prescribed fire).

	√ Fire effects (canopy cover after fire, fuel and duff moisture at time of fire). The model supplies some of the plant life history data, but other data can be obtained from local botanists or natural historians. Thinning and fire effects data can be obtained from FFE-FVS runs or from expert opinion.
Outputs	√ Predictions for plant survivorship (thinning mortality, fire mortality, nutrient effects, clonal growth effects, weed effects, canopy effects, shrub damage, and survivorship sum, which is a qualitative measure of change in plant biomass from pretreatment conditions). √ Predictions for plant reproduction (stored seeds; onsite colonization; offsite colonization; weed effects; mineral soil effects; canopy effects; and reproduction sum, which is a qualitative measure of the potential for a plant to colonize or recolonize an area after fuels reduction).
Linkage to other	URM does not link directly to any other program. However, outputs from FOFEM or FFE-FVS will help in providing inputs to URM. Output from URM will help in providing inputs to the Wildlife Habitat Response Model. URM is part of a set of tools online at http://www.fs.fed.us/fire/tech_transfer/synthesis/synthesis_index.htm.
Developers (partners)	USDA Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory USDI Bureau of Land Management.
Current status	URM was developed as part of the Fuel Planning Project-Science Synthesis and Integration (http://forest.moscowfsl.wsu.edu/fuels).
Training availability	Training materials are available at the Web site listed above. Additional training opportunities and distribution are planned.

Technical documentation	Sutherland, S.; Miller M. [In press]. Predicting the impact of fuels reduction on understory species: the understory response model. In: Sutherland, E.K.; Black, A., eds. Estimating the environmental consequences of fuels treatments: users guide. Gen. Tech. Rep. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Sutherland, S.; Miller M. [In press]. Evaluating the effects of alternative fuels treatments on understory vegetation. In: Sutherland, E.K.; Black, A., eds. Estimating the environmental consequences of fuels treatments: users guide. Gen. Tech. Rep. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. A draft of the User's Guide is available online at http://forest.moscowfsl.wsu.edu/fuels.
Contact	Steve Sutherland USDA Forest Service (406) 329-4813 ssutherland@fs.fed.us
Additional information	A Web site with background information, additional models, draft user guides, examples of model applications, and a series of two-page fact sheets describing various aspects of environmental consequences of fuel reduction can be found at http://forest.moscowfsl.wsu.edu/fuels/.

Valuation of Ecosystem Restoration Strategies (VERSTRA)

Application for fuel treatment	The primary application of the model is to assess the cost or revenue associated with treatments allocated on a subject landscape. These treatments can be fuel treatments, stand density reductions, timber harvest, or any other activity that involves removal of trees.
Description	VERSTRA was designed to read FVS cut-tree lists associated with a given management scenario and determine their product potential. The gross value of products is then merged with information on individual polygons to derive access and net value or cost of an operation (gross product value, logging costs, hauling costs). Another version of VERSTRA assigns a cut-tree list to management activities imposed by the state-transition model VDDT, then similarly determines the net value of potential products and the logging and hauling costs associated with utilizing the removed material.
Appropriate spatial scale	VERSTRA was designed to help assess implications of management activities and policies on the scale of 100,000- to 500,000-acre watersheds, although smaller and larger areas can be accommodated.
Analyst requirement	Analytical requirements for VERSTRA are low. The user simply specifies an input file that must be in FVS format and the output file to which the polygon-level information will be written.
Data inputs	√ Cut-tree list in FVS format. √ Other data are stored in text files, but can be changed by the user to account for local differences in log prices, logging costs, hauling costs, and stem taper.
Outputs	Visually displayed in a GIS are: √ Indices of accessibility √ Product potential √ Revenue potential √ Integrated utilization index

	√ Polygon number, CVS plot number representing the polygon, total cubic volume, total chip log volume, board foot volume, gross revenue, and net revenue for each polygon.
Linkage to other models/tools	VERSTRA was designed to be an integral part of the Landscape Visualization System (LVS) developed as part of the Inland Northwest Landscape Analysis System (INLAS). It also links to FVS and VDDT/TELSA if tree lists can be generated.
Developers (partners)	Oregon State University (Forest Service Pacific Northwest Research Station)
Current status	Testing ongoing in the context of VDDT/TELSA.
Training availability	None.
Technical documentation	None.
Contact	Doug Maguire Oregon State University (541) 737-2244 doug.maguire@oregonstate.edu
Additional information	None.

Vegetation Dynamics Development Tool (VDDT)

Application for fuel treatment	VDDT is used to examine changes in vegetation/fuel conditions given different management scenarios, natural disturbance regimes, and assumed long-term trends (e.g., climate warming). Results are not spatial, so spatial strategies for fuel treatments cannot be examined. However, the model is useful for estimating vegetation, fuel, and fire trends given different management approaches.
Description	VDDT is a state and transition model that can be used to model the short- and long-term interactions of vegetation, management, and disturbance. Most analysts use it to depict vegetation as structure (e.g., grass/shrub, seedling, sapling, pole, etc.) and cover (e.g., dominant species group) classes connected by growth, succession, management activities, and natural disturbances. VDDT can be used for any system that connects state classes through probabilities of different kinds of changes. VDDT is not spatial. It produces a variety of database and graphical outputs, but not maps.
Appropriate spatial scale	VDDT can be used at any scale through the appropriate choice of state classes (usually vegetation types). VDDT is often used for medium to large spatial scales for which other modeling systems tend to become difficult to assemble, data intensive, and time-consuming to run.
Analyst requirement	VDDT is becoming increasingly easy to use through the development of user interfaces that use EXCEL spreadsheets and ACCESS databases, but still requires thoughtful assembly and local expertise on vegetation types, disturbances, and management activities.
Data inputs	VDDT models are generally built by an analyst, resource specialist, or planner using local expert opinion, existing data, and available literature. The process requires developing vegetation state classes useful in addressing important issues (e.g., fire risks, wildlife habitats, forest

products, recreation, and others); defining growth, succession, response to management, and response to natural disturbance timelines or probabilities (expert opinion, literature, FVS or other models); and reviewing model outputs. Current vegetation condition is generally taken from GIS layers (pixel or polygon) and used to supply current condition by vegetation state class. Potential vegetation is often used to stratify models and account for different environments, disturbance regimes, and productivity. Several different management allocations can be used by adjusting disturbance probabilities, so GIS coverage of allocation and land ownership is useful.

Outputs	Graphic displays of state class conditions, disturbances, management activities, and calculated or other assigned attributes over time. VDDT can generate time step-by-time step output of percentages and area of the landscape in vegetation state classes, management activities, and natural disturbances. Output can be easily imported to spreadsheets or databases for further analyses. Model runs of several hundred years typically require only a few minutes, and many runs using randomly chosen initial probability seeds can be run for statistical analysis.
Linkage to other models/tools	VDDT models feed directly into the TELSA modeling process, which is spatial. FVS and other simulation tools can be used to develop VDDT pathways and probabilities. Any other model or tool that uses vegetation state classes (e.g., FRAGSTATS, Bayesian Belief Network, INFORMS, others) can supply input to or use data from VDDT. This is especially easy when spreadsheets or databases are used to supply or analyze output.
Developers (partners)	Forest Service Pacific Northwest Research Station (ESSA Inc., Vancouver, British Columbia)

Current status	Available to Forest Service and Bureau of Land Management without charge at http://ww.essa.com. A password to unzip the downloaded file can be obtained free of charge from the ESSA Web site. The model is currently being used for forest planning at many locations in the United States and is an integral part of LANDFIRE and FRCC.
Training availability	Training courses can be arranged through ESSA Technologies at http://www.essa.com/training/index.htm.
Technical	ESSA Technologies Ltd. 2005. Vegetation dynamics development tool user guide, Version 5.1. Vancouver, BC. 188 p. http://www.essa.com/downloads/vddt/VDDT-51-User-Guide.pdf
Contact	Sarah Beukema ESSA Technologies Ltd. (604) 733-2996 sbeukema@essa.com
Additional information	Publications can be found at http://www.essa.com/downloads/vddt/reppub.htm.

Water Erosion Prediction Project (WEPP) Fuel Management (FuMe) Tool

Application for fuel treatment	WEPP FuMe estimates sediment generated by fuel management activities.
Description	WEPP FuMe estimates background erosion rates and compares sediment loads and erosion from wildfire, thinning, prescribed fire, and low- and high-use road networks for a given topography. Soil and water databases are the same as those used for WEPP. It is intended to be used as a planning tool for NEPA analysis and similar documentation.
Appropriate spatial scale	Small.
Analyst requirement	WEPP FuMe is an online interface that can be run with any recent Web browser.
Data inputs	√ Climate √ Soil texture √ Road density √ Length(s) of treated hillslope(s) √ Length(s) of untreated buffers(s) √ Hillslope gradient √ Time between disturbances
Outputs	Twelve output runs determining long-term averages based on time between disturbances. A narrative is then presented that aids the user in interpreting and reporting on the results.
Linkage to other models/tools	WEPP FuMe is part of a set of tools online at http://forest.moscowfsl.wsu.edu/fuels.
Developers (partners)	USDA Forest Service, Rocky Mountain, Pacific Northwest, North Central, and Pacific Southwest Research Stations
Current status	Available.
Training availability	Unknown.

Technical documentation	Elliot, W.J.; Wu, J.Q. 2005. Predicting cumulative watershed effects of fuel management with improved WEPP technology. In: Moglen, G.E., ed., Managing watersheds for human and natural impacts: engineering, ecological, and economic challenges: proceedings of the 2005 Watershed Management Conference. Reston, VA: American Society of Civil Engineers. http://www.pubs.asce.org.
	Elliot, W.J. 2004. WEPP Internet interfaces for forest erosion prediction. Paper No. 02021. Journal of the American Water Resources Association (JAWRA). 40(2): 299-309.
Contact	William Elliot USDA Forest Service (208) 883-2338 welliot@fs.fed.us
Additional information	WEPP FuMe models only hillslope surface erosion processes. It does not model channel processes such as sediment transport and gullying. The interface does not model landslides on disturbed hillslopes or on road networks.

Wildlife Habitat Response Model (WHRM)

Application for fuel treatment	Assists forest planners and specialists in evaluating alternative fuel treatments on terrestrial wildlife habitats in dry interior forests of the Western United States.
Description	The Wildlife Habitat Response Model (WHRM) is a Web-based computer tool for evaluating the potential effects of fuel-reduction projects on terrestrial wildlife habitats. The WHRM uses species-habitat associations in ponderosa pine, dry-type Douglas-fir, lodgepole pine, and mixed-conifer forests to qualitatively predict how changes in critical habitat elements may affect wildlife habitat suitability of treated stands. Organizing potential responses of fauna into a conceptual framework based on knowledge of habitat requirements can help predict outcomes of fuel treatments, even when first-hand information about treatment effects does not exist.
Appropriate spatial scale	Small.
Analyst requirement	Low.
Data inputs	Users input the percentage of change in key habitat elements based on fuel treatment objectives or desired future conditions, or predicted from computer simulations such as the Forest Vegetation Simulator with the Fire and Fuels Extension (FFE-FVS). A keyword file is available for FVS users that will automatically generate these reports. The WHRM uses relative change values (percentage of change from pretreatment to posttreatment). Some habitat elements are subdivided into size classes. These elements include:

√ Bare mineral soil
√ Litter
√ Duff
√ Forbs
√ Grasses
√ Snags
√ Crown base height
√ Shrubs
√ Tree canopy cover
√ Down wood
√ Live trees

Outputs	Predicted effects on the various habitat requirements in qualitative terms: positive, null, or negative, and some summary text about the results.
Linkage to other models/tools	Input data can come from FFE-FVS. WHRM is part of a set of tools online at http://forest.moscowfsl.wsu.edu/fuels.
Developers (partners)	USDA Forest Service, Rocky Mountain Research Station
Current status	WHRM is in nearly final form and currently under review. The literature used in WHRM has already been published and was reviewed according to the standards of the individual publishers. The model itself is under open review by academic, federal, and nongovernmental organization scientists with expertise in various taxonomic groups and species. In the end, all products related to WHRM will have undergone rigorous review and will conform to the standards of the Data Quality Act (Federal Register 2002, Office of Management and Budget 2004).
Training availability	Unknown.
Technical documentation	http://forest.moscowfsl.wsu.edu/fuels/whrm/index.html Documentation is in draft form and cannot be cited or referenced.
Contact	Elaine Kennedy Sutherland USDA Forest Service (406) 542-4150 esutherland@fs.fed.us
Additional information	The WHRM does not make quantitative predictions, nor does it predict population-level responses of wildlife species. The WHRM does not include inter- and intraspecific interactions such as competition among species, nor environmental or demographic random events. The WHRM does not have a temporal scale, but users can predict changes over time by altering the habitat elements appropriately. This can be effectively accomplished by referring to FFE-FVS habitat element predictions at 1, 5, and 10 years.

Appendix 2: Acronyms and Models

AF	Available fuel
AML	Software architecture meta-language
APACK	An analysis package for rapid calculation of landscape metrics on large-scale data
Biome-BGC	A terrestrial ecosystem model
BlueSky	BlueSky Smoke Forecast System
CALPUFF	An air quality dispersion model
CANOCO	A program for canonical community ordination
CF	Crown fire
CLAMS	Coastal Landscape Analysis and Modeling study
Consume	Software that calculates consumption and emissions of fires
CRAFT	Comparative Risk Assessment in Fire and Fuels Planning model
CrownMass	Assessment of potential fire behavior
CVS	Current Vegetation Survey
DAYMET	Model that generates daily surfaces of temperature, precipitation, humidity, and radiation over large regions of complex terrain.
DEBMOD	Debris prediction program
DEM	Digital elevation model
EPA	Environmental Protection Agency
EPM	Emission Production Model
ERC	Energy release component
FACTS	Forest Service Activity Tracking System
FARSITE	Fire area spread simulation model
FASTRACS	Fuel Analysis, Smoke Tracking, and Report Access Computer system
FB	Fire behavior
FBAT	Fire Behavior Assessment Tool
FCAMMS	Fire Consortia for Advanced Modeling of Meteorology and Smoke
FCC	Fire Condition Class
FCCS	Fuel Characteristic Classification System
FEPS	Fire Emission Production Simulator
FETM	Fire Effects Tradeoff Model
FFE	Fire and Fuels Extension
FIA	Forest Inventory and Analysis
FIREMON	Fire Effects Monitoring and Inventory System

FMA	Fire Management Analyst®
FOFEM	First Order Fire Effects Model
FRAGSTATS	A program that calculates landscape measurements and statistics
FRCC	Fire Regime Condition Class
FUELSOLVE	Optimizing fuel solutions and ecological values in landscapes
FVS	Forest Vegetation Simulator
GIS	Geographic information systems
HCR	Harvest Cost and Revenue estimator
HUC	Hydrologic unit code
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory model
IAN	A raster image analysis software program
IIAA	Interagency Initial Attack Assessment
INFORMS	Integrated resource management system
LANDFIRE	Interagency vegetation and fuel mapping project
LANDSUM	Landscape Succession Model
LINKAGES	A linked forest productivity-soil water, carbon, and nitrogen model
LMS	Landscape Management System
MAGIS	Multiresource Analysis and Geographic Information System
MM5	Mesoscale atmospheric circulation model
MSN	Most Similar Neighbor
MyFTP	My Fuel Treatment Planner
NEPA	National Environmental Policy Act
NEXUS	An Excel spreadsheet that links surface and crown-fire prediction models
NFDR	National Fire Danger Rating
NFDRS	National Fire Danger Rating System
NFPORS	National Fire Plan Operations and Reporting System
NOAA	National Oceanographic and Atmospheric Administration
NOCLAMMS	Northeastern Cascades Landscape Analysis Management and Monitoring System
NVCS	National Vegetation Classification Standard
PCHA	Personal Computer Historic Analysis
PCORD	Program that performs multivariate statistical analysis of ecological data, including cluster analysis, ordination, and species diversity.

PM2.5	Particulate matter less than 2.5 microns in diameter
PnET-II	A forest carbon and water balance model
PNVG	Potential natural vegetation group
PM10	Particulate matter less than 10 microns in diameter
PRMS	Precipitation Runoff Modeling System
RAINS	Rapid Access Information System
RAWS	Remote Automated Weather Stations
RAZU	A smoke management Web application
RERAP	Rare Event Risk Analysis Process
RMLANDS	Rocky Mountain Landscape Simulator
RX-310	Introduction to Fire Effects class
S-491	Intermediate National Fire Danger Rating System class
S-493	Fire Area Simulation clas
SAF	Society of American Foresters
SASEM	Simple Approach Smoke Estimation Model
SIG	Special interest group
SIS	Smoke Impact Spreadsheet model
SPECTRUM	An economic scheduling model
SRM	Society for Range Management
STHARVEST	Simulates the cost of harvesting
SVS	Stand Visualization System
TELSA	Tool for Exploratory Landscape Scenario Analysis
URM	Understory Response Model
VDDT	Vegetation Development Dynamics Tool
WHRM	Wildlife Habitat Response Model
WIMS	Weather Information Management System
WXFIRE	A weather program that extrapolates and summarizes DAYMET weather to finer resolutions

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