A Suite of Fire, Fuels, and Smoke Management Tools

Roger D. Ottmar, Clint S. Wright, and Susan J. Prichard

The Fire and Environmental Research Applications Team (FERA) of the Forest Service, Pacific Northwest Research Station, is an interdisciplinary team of scientists that conduct primary research on wildland fire and provide decision support for fire hazard and smoke management. The team is committed to providing easy-to-use tools that help managers in their fire and fuels planning. Several tools developed by FERA include:

- *Natural Fuels Photo Series (NFPS).* These published photo series volumes (available through <http://www.fs.fed.us/pnw/fera/research/fuels/photo_series/>) provide a quick and easy way to quantify and describe fuel and vegetation characteristics.
- *Digital Photo Series (DPS).* This Web-based application (<http://depts.washington.edu/nwfire/dps>) makes it easy for users to search for existing fuels data and high-quality photographs of the NFPS.
- *Fuel Characteristic Classification System (FCCS).* FCCS allows users to build fuelbeds and assess them for their relative fire hazard, surface fire behavior, and potential carbon stores. See <http://www.fs.fed.us/pnw/fera/fccs/>.
- *Consume 3.0.* Consume provides users the ability to estimate fuel consumption and emissions from fuelbeds burned during prescribed and wildland fires. See <http://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml> for more details.
- *Fire Emission Production Simulator (FEPS).* FEPS enables users to estimate the rate of fuel consumption, heat release, and emissions production from fuelbeds burned during prescribed and wildland fires. The application can be downloaded from <http://www.fs.fed.us/pnw/fera/feps/>.

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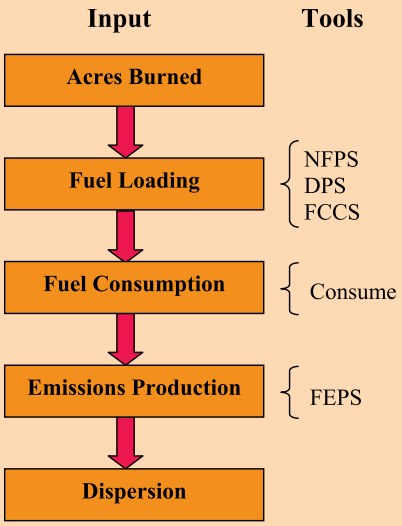
FERA tools are used to estimate wildland fire emissions



The tools can be used individually or in combination to support a variety of management situations. For example, for a fuel reduction project, managers may need to first assess fuel characteristics, including the loading and configuration of wildland fuels. The NFPS and DPS contain a wealth of fuels information and can be used to quickly and inexpensively assess fuel characteristics. FCCS can be used to build custom fuelbeds based on actual fuel assessment data. Managers then can evaluate potential fire behavior and fire hazard in FCCS and explore different fuel reduction scenarios. If prescribed fire is planned as a fuel reduction strategy, Consume and FEPS can be used to estimate potential fuel consumption and pollutant emissions for each custom fuelbed.

Natural Fuels Photo Series

NFPS provides a quick and easy way to quantify and describe current fuel and vegetation properties, such as loading of dead and down woody material, tree density, or height of understory vegetation. This information is critical for making fuel management decisions and predicting fire behavior and fire effects. NFPS currently comprises 14 volumes representing various regions and fuel types of the United States and two volumes representing Mexico and Brazil. A significant national effort over the last decade resulted in publication of NFPS for previously unrepresented vegetation types. Future photo series will

include a hurricane damage series for the Southern United States and a volume focusing on relevant fuelbed types in the San Francisco Bay area.

Each volume contains up to four photo series for 1 to 17 sites. Series for each site include standard, wide-angle, and stereo-pair photographs and inventory data summarizing:

- vegetation composition, structure, and loading; woody material loading;
- density by size class, forest floor depth, and loading; and
- various site characteristics.

The photo series are important land management tools that can be used to assess ecological landscapes through appraisal of living and dead woody material, vegetation biomass, and stand characteristics. 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.

Digital Photo Series

NFPS was developed primarily for field-based assessments. Technological advances, coupled with development of new fire- and natural resource-based software applications, highlighted the need for an electronic version of the photo series. DPS was the result (see Wright and others, in this volume, for a more detailed description). DPS provides easy access to data and images from all of the volumes, series, and sites in the NFPS. Information presented in this new format can be used for planning fuels treatments or other management actions and as inputs to fire behavior and fire effects models and applications. DPS has the ability to grow as new photo series are developed and as the priorities and needs of fire and fuels managers change and evolve.

Published volumes of the Natural Fuels Photo Series.

Region	Fuelbed Type(s)	Volume
Pacific Northwest	Mixed-conifer with mortality, western juniper, sagebrush, grassland	I[1]
Alaska	Black spruce, white spruce	II[1]
Alaska	Hardwoods with spruce	IIa[1]
Rocky Mountains	Lodgepole pine, quaking aspen, gambel oak	III[1]
Southwest	Pinyon-juniper, chaparral, sagebrush	IV[1]
Midwest	Red and white pine, northern tallgrass prairie, mixed oak	V[1]
Lake States	Jack pine	Va[1]
Southeast	Longleaf pine, pocosin, marshgrass	VI[1]
Southeast	Sand hill, sand pine scrub, hardwoods with white pine	VIa[1]
West Coast	Oregon white oak, California deciduous oak, mixed-conifer with shrub	VII[1]
Northeast	Hardwood, pitch pine, red spruce/balsam fir	VIII[1]
Southwest	Oak/juniper	IX[2]
Montana	Sagebrush with grass, ponderosa pine-juniper,	X[2]
Hawaii	Grassland, shrubland, woodland, forest	N/A[2]
Brazil	Cerrado	N/A[2]
Mexico	Montane subtropical forests, temperate forests, montane shrublands	N/A[2]
Southeast	Hurricane damaged pine	N/A[3]

[1] *Photo series can be purchased from the National Interagency Fire Center in Boise, ID, for a nominal charge.*
[2] *Photo series can be requested free of charge from the Fire and Environmental Research Applications Team.*
[3] *This photo series is in preparation; expected publication is spring 2009.*

Photo series photograph from the new hurricane damage photo series that is in preparation.

Fuelbed strata and categories in the FCCS

Stratum	Category
CANOPY	Trees, snags, ladder fuels
SHRUBS	Primary and secondary layers
NONWOODY VEGETATION	Primary and secondary layers
WOODY FUELS	All wood, sound wood, rotten wood, stumps, and woody fuel accumulations
LITTER-LICHEN-MOSS	Litter, lichen, and moss layers
GROUND FUELS	Duff, basal accumulations, and squirrel middens

Application of NFPS and DPS

NFPS and DPS are useful tools in several branches of natural resource science and management. Inventory data provided by these tools can be used as inputs for evaluating animal and insect habitat, nutrient cycling, and microclimates. Fire managers will find these data useful for predicting fuel consumption, smoke production, fire behavior, and fire effects during wildfires and prescribed fires. In addition, the photo series can be used to appraise carbon sequestration, an important factor in predictions of future climate, and to link remotely sensed signatures to live and dead fuels on the ground.

FCCS

FCCS enables land managers to create and catalog fuelbeds for fuels and fire planning. It contains searchable fuelbed data sets that represent much of North America and were compiled from scientific literature, natural fuels photo series, fuels data sets, and expert opinion. The system allows customization of these fuelbeds or creation of new fuelbeds to represent a particular situation or scale of interest. FCCS reports assigned and calculated fuel characteristic for each of six fuelbed strata, including the canopy, shrubs, nonwoody, woody, litter-lichen-moss, and duff.

FCCS calculates the relative fire hazard of each fuelbed, including surface fire behavior, crown fire, and available fuel potentials, scaled on an index from 0 to 9. The FCCS also uses a modified version of the Rothermel surface fire behavior equations (Rothermel 1972, Sandberg and others 2007) to predict actual surface fire behavior,

including reaction intensity (Btu ft^{-2} min^{-1}), flame length (ft), and rate of spread (ft min^{-1}), and based on both benchmark and user-specified environmental conditions. By comparing predicted flame length and rate of spread, FCCS provides a crosswalk to any of the original 13 Fire Behavior Prediction System fuel models (Albini 1976) and to any of the 40 standard fire behavior fuel models (Scott and Burgan 2005). FCCS also reports carbon storage by fuelbed stratum, category, and subcategory and predicts the amount of combustible carbon based on selected fuel moisture scenarios. Finally, the system reports in English and metric units, provides the capability to upload photos to represent fuelbeds, and can be run in a batch mode to provide outputs for multiple fuelbeds simultaneously.

Acronyms

DPS	Digital Photo Series
FCCS	Fuel Characteristic Classification System
FEPS	Fire Emision Production Simulator
FERA	Fire and Environmental Research Applications Team
FIREMON	Fire Effects Monitoring and Inventory Protocol
FOFEM	First Order Fire Effects Model
FVS	Forest Vegetation Simulator
NFPS	Natural Fuels Photo Series

Application of the FCCS

FCCS facilitates the mapping of fuelbed characteristics and fire hazard assessment by storing realistic fuelbed data, summarizing and calculating fuel characteristics, and predicting surface fire behavior, crown fire behavior, and available fuel for consumption. FCCS also provides the necessary inputs to run fuel consumption and emission production models, such as Consume and FEPS.

FCCS fuelbeds are being mapped on the Okanogan-Wenatchee and Deschutes National Forests to allow managers to evaluate fire hazard and maximize fuel treatment effectiveness. The U.S. Environmental Protection Agency is developing a national air pollutant and carbon emission inventory based on FCCS fuelbeds (fig. 1). LANDFIRE (a project producing consistent and comprehensive maps and data describing vegetation, wildland fuel, and fire regimes across the United States) (Rollins and others 2006) is also developing a 30-meter resolution map layer of FCCS fuelbeds for the United States.

FCCS was introduced to managers and scientists during 15 national workshops and through 8 pub-

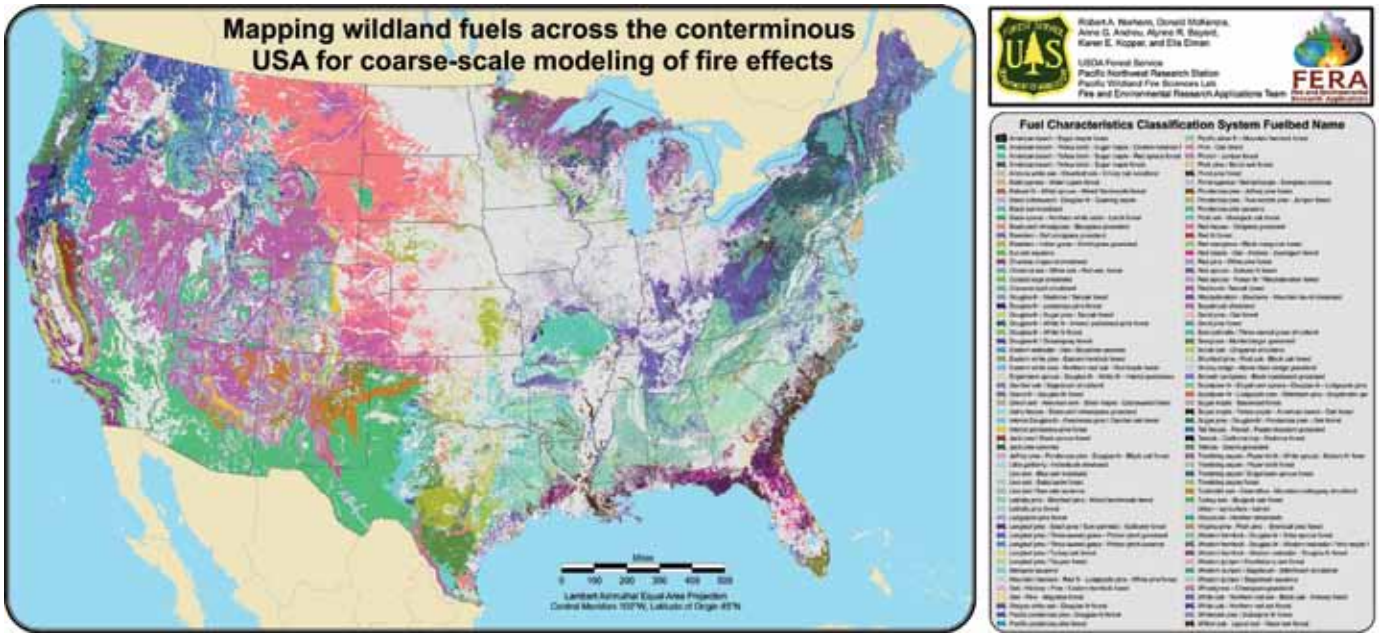


Figure 1—*One-km resolution FCCS fuelbed data are available for the continental United States (map available through <http://www.fs.fed.us/pnw/fera/fccs/maps.shtml>).*

The photo series are important land management tools that can be used to assess ecological landscapes through appraisal of living and dead woody material and vegetation biomass and stand characteristics.

lished papers in a special section of the Canadian Journal of Forest Research (Berg 2007; Ottmar and others 2007; Riccardi and others 2007a; Riccardi and others 2007b; Sandberg and others 2007a; Sandberg and others 2007b; Schaaf and others 2007; McKenzie and others 2007). Source data references for each fuelbed, as well as supplementary fuelbeds useful to specific locations and purposes, can be found on the FCCS Web site (<http://www.fs.fed.us/pnw/fera/fccs>). In future versions, linkages with other FERA tools, Fire Effects Monitoring and Inventory Protocol (FIREMON), the First Order Fire Effects Model (FOFEM) (Reinhardt and others 1997), and the Forest Vegetation Simulator (FVS) (Dixon 2003) are envisioned.

Consume 3.0

Fuel consumption is a key variable in fire effects modeling and in understanding when and how fire should be applied to meet site and landscape objectives while at the same time mitigating air quality impacts. Until recently, much of the considerable research on fuel consumption focused on prescribed burning following logging in forested ecosystems. FERA's new fuel consumption studies in natural environments (developed with support from the Joint Fire Science Program and the National Fire Plan) have improved our understanding of fuel consumption in shrublands (including chaparral, sagebrush, and palmetto-galberry types), hardwood forests (including southern and eastern regions of the United States), and boreal forests (including white spruce, black spruce, and hardwood forests of Alaska). Consume also resolves differences in fuel consumption between the relatively short flaming phase of combustion and the longer smoldering phase of combustion that generally contributes to the majority of wildland fire emissions.

Consume is a decisionmaking tool designed to assist resource managers in planning for prescribed fire and wildfire, and reflects our improved understanding of fuel consumption and emissions in wildland fire throughout major fuel types in the United States.

For Further Information, visit:

Fuel Characteristic Classification System:
<http://www.fs.fed.us/pnw/fera/fccs>.

Natural Fuels Photo Series:
<http://www.fs.fed.us/pnw/fera/research/fuels/photoseries>.

Consume 3.0:
<http://www.fs.fed.us/pnw/fera/research/smoke/consume>.

Fire Emission Production Simulator:
<http://www.fs.fed.us/pnw/fera/feps>.

Consume predicts fuel consumption, pollutant emissions, and heat release based on a number of variables, including fuel loadings, fuel moisture, and other environmental factors. Using these predictions, resource managers can determine when and where to conduct a prescribed burn or to plan for a wildland fire to achieve desired objectives while reducing the impact on other resources.

Consume allows land managers and researchers to input fuel characteristics, lighting patterns, fuel conditions, and meteorology to more accurately predict fuel consumption and emissions. Consume can import data from the FCCS, and its reports are formatted to feed other models (e.g., FEPS), as well as for inclusion in burn and smoke management plans.

Application of Consume 3.0

Consume can be used to estimate fuel consumption and emissions from wildland fire in most forests, woodlands, shrublands, and grasslands of North America. The outputs provide managers with fuel consumption and emissions information for fire planning and for meeting smoke management reporting requirements. Fuelbed data are the basis for all Consume calculations. Because fuelbeds can represent any scale of interest, Consume can be applied to small-scale fuel reduction projects and to large-scale landscape assessments of consumption and emissions. For example, on smaller scales, Consume can be used to develop burn prescriptions for prescribed fire planning. On a much larger scale, the BlueSky smoke modeling framework (O'Neil 2003) (<http://www.airfire.org/bluesky>), uses

Consume algorithms to estimate emissions to predict smoke impacts across landscapes.

Fire Emissions Production Simulator

Modeling the impact of emissions from wildland fire on visibility and public health requires the rates as well as the total amount of fuel consumption, heat release, and emissions production. These rates are required inputs for smoke dispersion models for assessing potential visibility and health impacts of smoke at a distance from the fire. FEPS, an update of the Emissions Production Model (EPM) (Sandberg and Peterson 1984), models the characteristics of prescribed burns and wildland fires. FEPS significantly improved the usability, applicability, and accuracy of EPM. FEPS 1.1 includes the fuels data from the most popular fuelbeds in the FCCS and produces hourly emission and heat release data for prescribed and wildland fires. It can also accept fuel consumption data generated by the FOFEM (Reinhardt and others 1997), Consume 2.1, and Consume 3.0.

FEPS distributes total fuel consumption amounts over the life of the burn to generate hourly emission and release information. FEPS allows users to produce reasonable results with very little information by providing default values and calculations while maintaining the ability of advanced users to customize data inputs to produce very refined results.

Application of FEPS

Hourly emission and heat release data for wildland fires in fuel types in the United States produced by FEPS 1.1 can be fed into dispersion models, such as the BlueSky smoke modeling framework (O'Neil and others 2003) and V-Smoke (Lavdas 1996) for assessing smoke impacts from wildland fire.

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Wind Models
Fuel Models
Forecasting Suppression Costs
Smoke Management

Fire Research

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This Issue...

This issue provides a glimpse into the role that research and technology play in the management of fires today and into the future. Over the years, the Forest Service and the interagency fire community have considered not only the science behind fire itself, but also the science of predicting fires and what is likely to happen when a fire-start occurs. Many aspects of fire management—fuels, wildland-urban expansion, and environmental factors among them—are different today than they were even a decade ago, making it more critical than ever to use emerging science and state-of-the-art methods of prediction to keep firefighters and the public safe. The articles in this issue reflect just a few of the models, tools, and approaches that are currently shaping and advancing the science and management of fire to achieve that end.

—Tory Henderson, Issue Coordinator

Erratum

In *Fire Management Today* vol. 69, no. 1 [Winter 2009], the caption for the photo of snow geese near a Marsh Master in the "Myth Busting about Wildlife" article gave an incorrect credit. It should have credited Drew Wilson, Virginia Pilot.

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