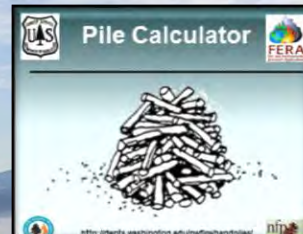


Managed/Prescribed fire Smoke Modeling from Forest to Plume



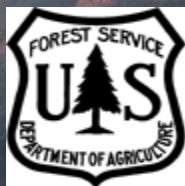
Susan Prichard, Susan O'Neill and Roger Ottmar

Fire and Environmental Research Applications Team

Pacific Wildland Fire Sciences Laboratory

Seattle, Washington

Website: www.fs.fed.us/pnw/fera



Smoke Modeling from Forest to Plume Workshop

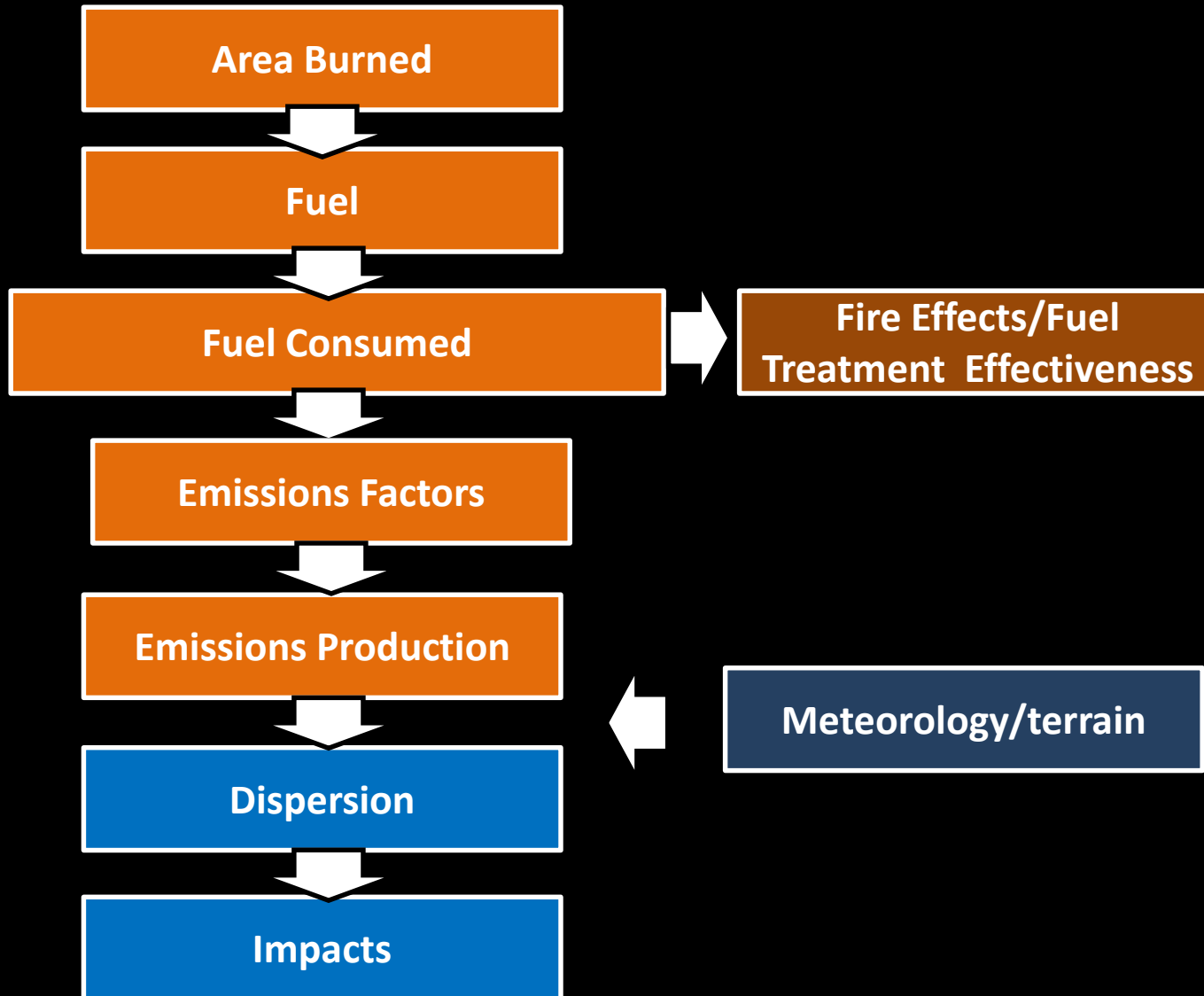
- Load FFT as needed 1200-1300 Prichard/Ottmar
- Welcome/Introduction 1300-1315 Prichard
- Overview of FFT 1315-1345 Ottmar
- Short stretch break 1345-1350 All
- FFT Demo 1350-1420 Prichard
- FFT Practical Exercise 1420-1520 Prichard/Ottmar
- Break 1520-1530 All
- Blue Sky etc. 1530-1700 O'Neill

Introductions and Other Information

An aerial photograph of a volcanic eruption. A large, dark, conical mountain is the source of a massive, billowing plume of white ash and grey smoke that rises into the sky. The plume is thick and textured, with some darker, rocky fragments visible within it. The surrounding landscape is a mix of green, forested hills and brown, rocky terrain. The overall scene is dramatic and powerful.

- **Cadre**
- **Participants**
- **Handouts**
 - Agenda
 - Fact sheets
 - Exercises

Smoke Modeling: FFT and BlueSky



<https://depts.washington.edu/fft/>

Fuel & Fire Tools (FFT)

Fuel & Fire Tools

An Integration of FCCS, Consume,
FEPS, The Pile Calculator,
and The Digital Photo Series

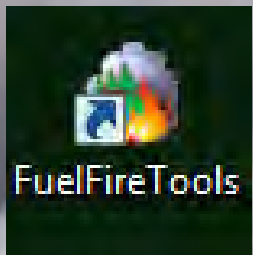


Choparral
Los Angeles, California

 USDA - Forest Service
Pacific Northwest Research Station
FERA Pacific Wildland Fire Sciences Laboratory
Fire and Environmental Research Applications Team
400 N 34th Street, Suite 201 • Seattle, WA 98103
206.732.7800 • www.fs.fed.us/pnw/fera • pnw_fccshelp@fs.fed.us



Don't show splash screen Continue

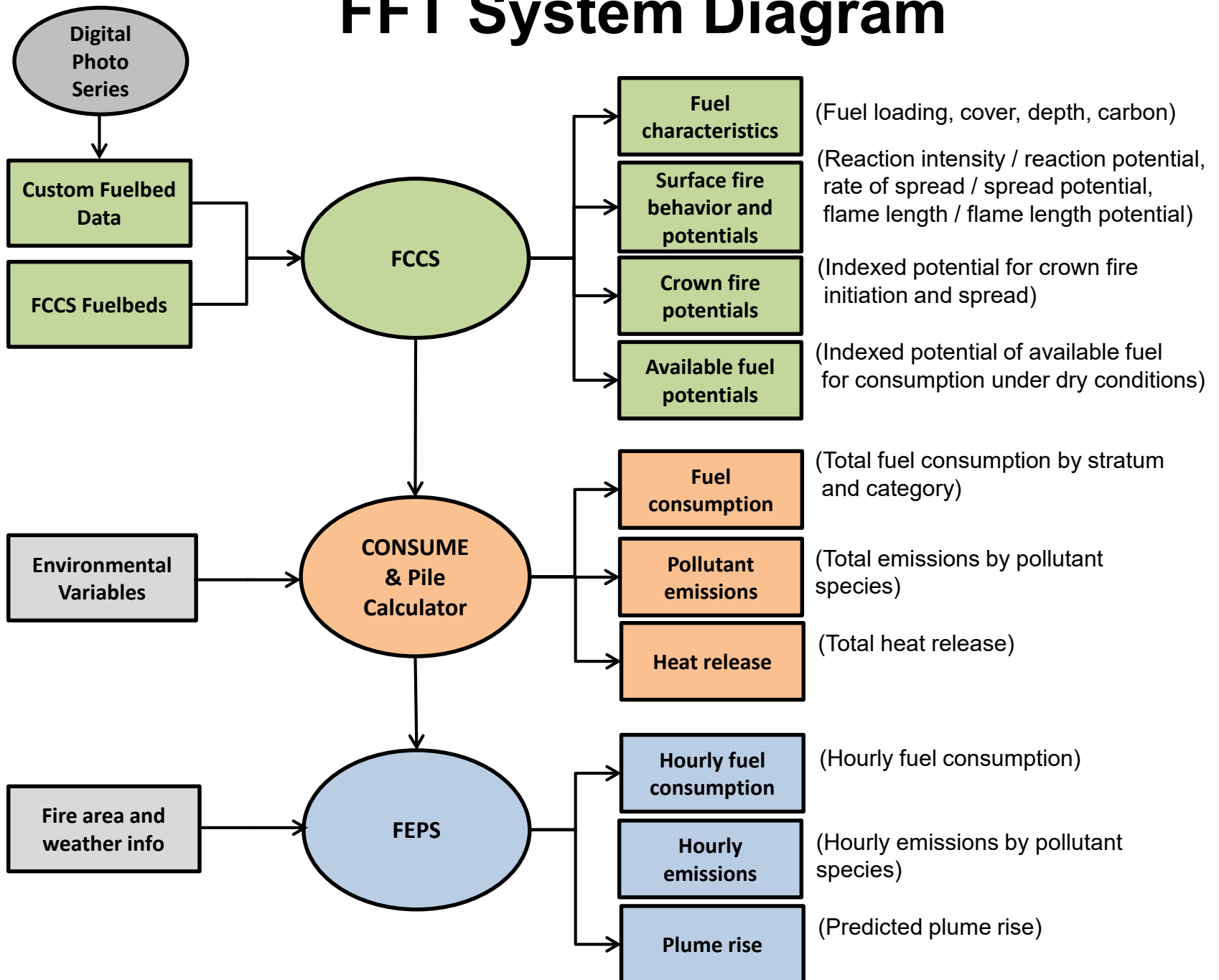


FuelFireTools

Version 1035

© 2017
376' MSL

FFT System Diagram



Natural Fuels Photo Series

Fire and Environmental Research Applications Team

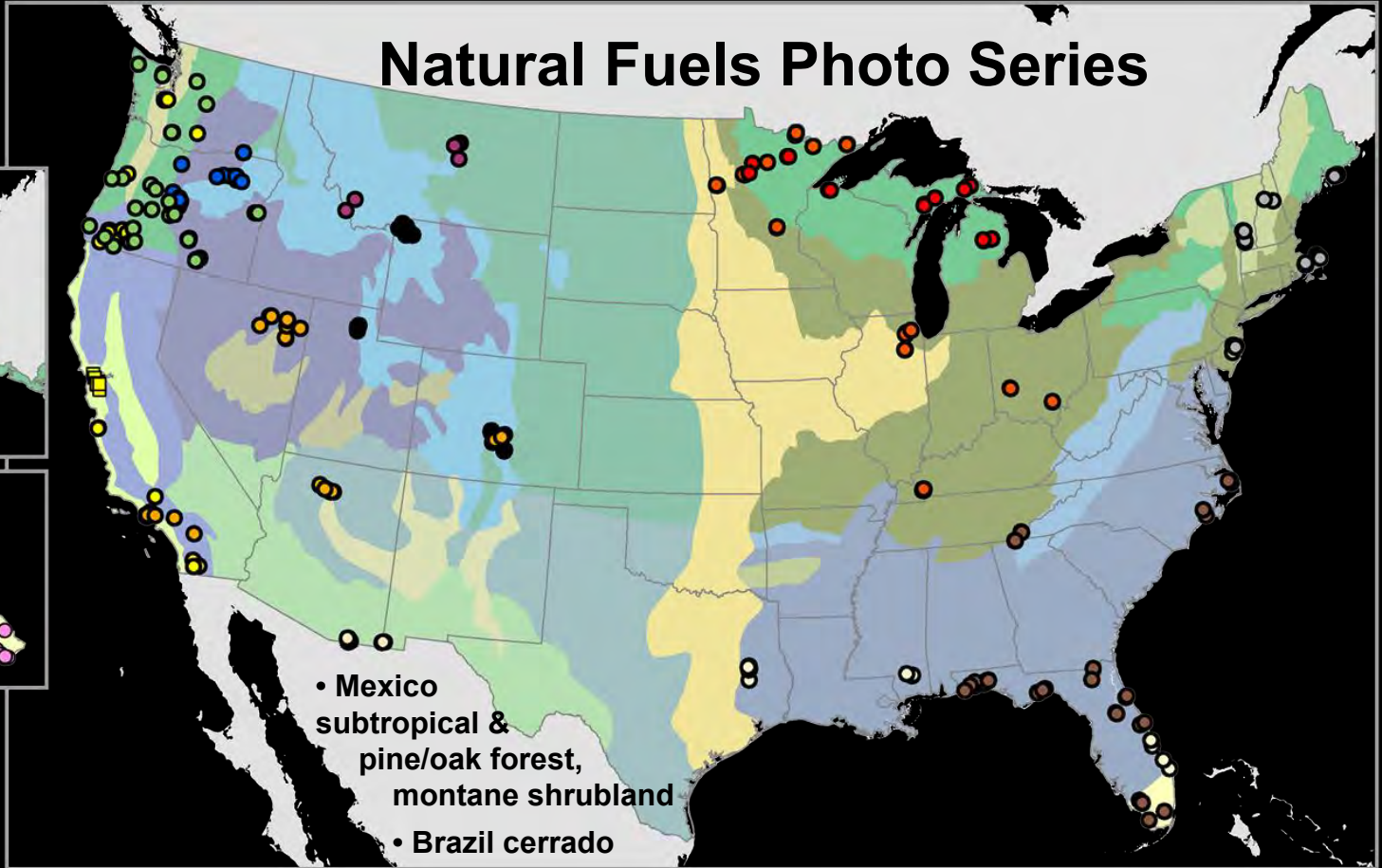
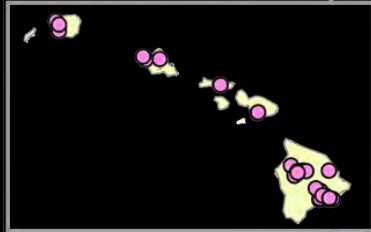
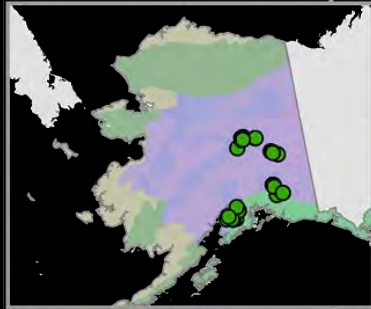
USFS Pacific Northwest Research Station

Seattle, Washington

Website: www.fs.fed.us/pnw/fera



Natural Fuels Photo Series



• Mexico
subtropical &
pine/oak forest,
montane shrubland

• Brazil cerrado



- | | | | |
|--------------------------------|------------------------------|----------------------------|--------------------------|
| ● Hawaii Grasslands | ○ Rocky Mt. Lodgepole Pine | ● SE U.S. Longleaf Pine | ● NE Hardwood |
| ● Hawaii Shrublands | ○ Rocky Mt. Gambel Oak | ● SE U.S. Pocosin-Woodland | ● Pitch Pine |
| ● Hawaii Woodlands | ○ Rocky Mt. Quaking Aspen | ● SE U.S. Pocosin-Shrub | ● Red Spruce/Balsam Fir |
| ● Hawaii Forests | ● SW U.S. Pinyon-Juniper | ● SE U.S. Marshgrass | ● Ponderosa Pine-Juniper |
| ● Interior PNW Mixed-Conifer | ● SW U.S. Chaparral | ● SE U.S. Sandhill | ● Sagebrush w/ Grass |
| ● Interior PNW Western Juniper | ● SW U.S. Sagebrush | ● SE U.S. Sand Pine Scrub | ● Sage Grouse Habitat |
| ● Interior PNW Sagebrush | ● Midwest Red and White Pine | ● SE U.S. Hardwoods | ● Spotted Owl Habitat |
| ● Interior PNW Grassland | ● Northern Tallgrass Prairie | ● Oregon White Oak | ■ East Bay Grassland |
| ● Alaska Black Spruce | ● Mixed Oak | ● California Deciduous Oak | ■ East Bay Shrubland |
| ● Alaska White Spruce | ● Jack Pine | ● Mixed-Conifer w/ Shrub | ■ East Bay Woodland |
| ● Alaska Hardwoods | ● SE U.S. Hurricane | ● Oak/Juniper Woodland | ■ East Bay Eucalyptus |

Digital Photo Series <http://depts.washington.edu/nwfire/dps>

- Web Application
- Database
- Interface
- English or Metric
- Searchable
 - Location
 - Vegetation type
 - Species
 - Fuel and stand data

Example → Search for sites with 'oak' in Washington:
7 sites in the Oregon White Oak series in Volume VII

Photo series site search [Digital photo series home]

To display sites of interest, click on the maps above, or use the form below and click "Get sites."

Photo Series: [] State: Washington Ecoregion: []
Land owner: [] Cover Type: []

Species:
General [] common name [] contains [] oak [] And [] General [] scientific name [] starts with []

Quantitative measurements: [] Measurement system: English []

Get sites Reset form

7 sites met the following criteria:
♦ State = Washington
♦ Common name contains 'oak'

Volume VII: Western United States

WO: Oregon White Oak


WO 02 WO 03 WO 06 WO 07 WO 08
WO 09 WO 10

Pile Calculator

- Machine and hand piles
- Biomass and emissions
 - smoke management
 - biomass management
 - regulatory compliance
- Batch processing function
- Export inputs/outputs
- Online and desktop



<http://depts.washington.edu/nwfire/piles>



Piled Fuels Biomass and Emissions Calculator

Last updated: 4/1/2011

1. DATA ENTRY MODE: **MANUAL** [Clear all/Start over] [Help]

2. MEASUREMENT SYSTEM: **ENGLISH**

3. Add Pile Group of Pile Type: Hand Machine

Describe this pile group:

Pile group name:

Number of piles:

Pile shape: Half sphere Paraboloid Half cylinder Half-truncated cone Cone w/ rounded ends Half ellipsoid Irregular solid

Pile dimensions (ft):

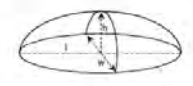
W1: W2:

H1: H2:

L1: L2:




Pile composition:

Consumption: % of piled material




Pile Group Data: (Click on Group No. to edit given group) [Export inputs to text]

Group No.	Group Name	No. Piles	Pile Type	Pile Shape	Pile Dimensions	Soil %	Packing Ratio	Pile Composition	Pile Quality	Consumption
1	OW-hand2	100	Hand	Half sphere	H1: 0	N/A	N/A	Conifer	N/A	90%

Fire and Environmental Research Applications Team
 Pacific Wildland Fire Sciences Laboratory
 US204 Forest Service Pacific Northwest Research Station
 400 N 34th Street, Suite 201, Seattle, WA 98103 (206) 732-7800
 Contact: Clint S. Wright (cwright@fs.fed.us)



We acknowledge funding from the Joint Fire Science Program under Projects JFSP 07-2-1-57 and JFSP 10-5-02-2.




Pile Group Data: (Click on Group No. to edit given group) [Export inputs to text]

Group No.	Group Name	No. Piles	Pile Type	Pile Shape	Pile Dimensions	Soil %	Packing Ratio	Pile Composition	Pile Quality	Consumption
1	OW-hand1	100	Hand	Half sphere	H1: 8	N/A	N/A	Conifer	N/A	90%


Pile Group Results: [Export results to text]

Pile Group No.	Pile Group Name	Gross Volume (cubic ft)	Adjusted* Volume (cubic ft)	Pile Biomass (tons)	Consumed Fuel (tons)	Emissions by pollutant (tons)						
						PM	PM10	PM2.5	CO	CO2	CH4	NMHC
1	OW-hand1	107,233.03	60,187.29	89.9688	80.9719	0.8866	0.6275	0.5466	3.0758	134.7134	0.2269	0.1832
TOTAL		107,233.03	60,187.29	89.9688	80.9719	0.8866	0.6275	0.5466	3.0758	134.7134	0.2269	0.1832

*Adjusted volume for hand piles is corrected to account for the difference between the gross volume of a geometric shape and the actual volume of the pile.
 Machine pile adjusted volume of solid wood is determined by subtracting the amount that is soil from the gross volume and applying the appropriate packing ratio.

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We acknowledge funding from the Joint Fire Science Program under Projects JFSP 07-2-1-57 and JFSP 10-5-02-2.

Fuel Characteristic Classification System (FCCS)

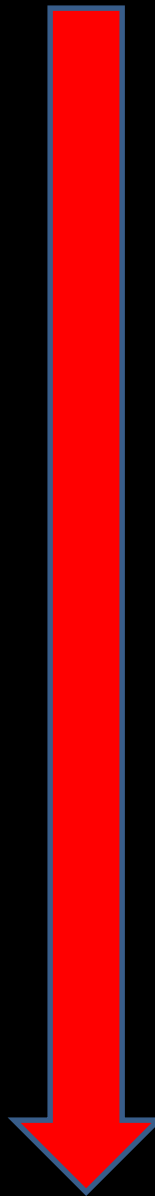




Simple



Complex





Seasonality

Natural Change Agents



Human Change Agents



Treatment Effectiveness



Carbon Accounting



Trees
Shrubs
Grasses
Woody
Litter
Duff

The Fuel Characteristic Classification System (FCCS)

A nationally consistent, durable system to build and characterize all components of a fuelbed and to classify the fuelbed for its potential flammability, fire hazard and carbon.

A photograph of a forest with many tall, thin trees and a large fallen log in the foreground. The text is overlaid on the image.

Because other fuel systems are designed for specific output requirements, the systems often :

- Include only a portion of fuelbed components
- Do not capture all the structural complexity, fuel characteristics, and geographic diversity of a fuelbed

What are the specifics of the FCCS?

Fuel Characteristic Classification System is:

✓ Composed of 3 elements:

- Fuel beds
 - FCCS fuelbeds
 - Customized fuelbeds
- Calculation of physical characteristics
- Calculation of FCCS fire potentials, fire behavior prediction, and fuel model crosswalk

What is a Fuelbed?



- Measured or averaged physical characteristics of a relatively uniform unit on the landscape that represent a distinct fire environment
- At any scale and precision of interest

Fuelbed Organization

Stratum

Category

Canopy



Trees



Snags



Ladder fuels

Shrub



Primary

Secondary

Herbaceous



Primary

Secondary

Woody



Sound



Rotten



Stumps



Piles

Litter-lichen-moss



Litter-lichen-moss

Ground fuels



Duff



Basal accumulations



Squirrel middens

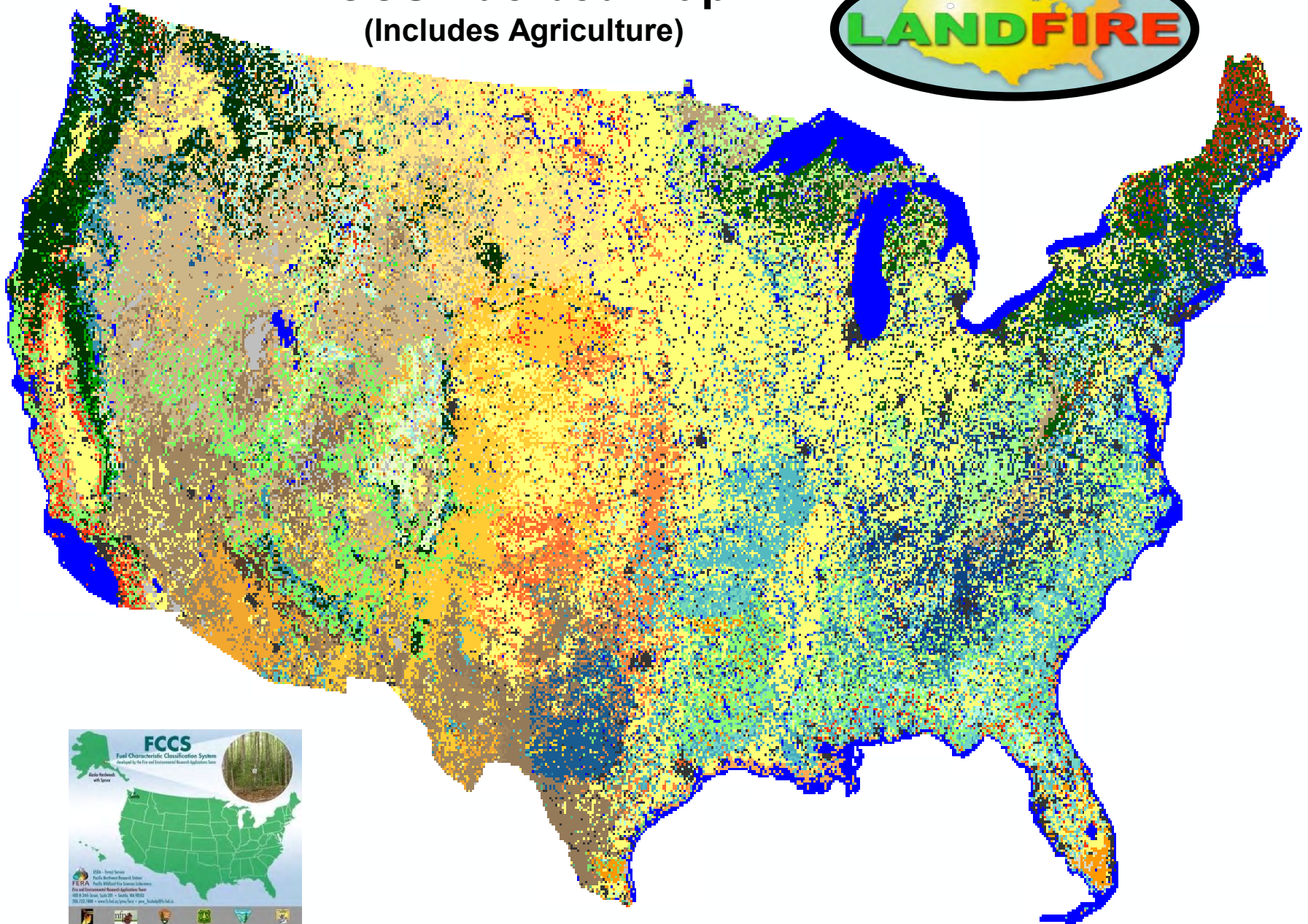
The fuelbed was designed to include all fuelbed components that could burn. It allows users to include, combine or exclude as much detail as needed for an application

FCCS Fuelbeds

- **FCCS data base contains 500+ reference fuelbeds internal to software**
 - **Represent a broad variety of common vegetation types**
 - **Associated change agents (e.g. fire, disease, insects, harvest, etc.)**
- **Regional fuelbed sets can be downloaded (Agricultural, Okanogan-Wenatchee, NE OR, central OR, Lake Tahoe, Savannah River Site)**
- **Soon: Mexico, south America, Mediterranean**

FCCS Fuelbed Map

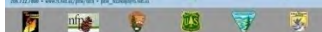
(Includes Agriculture)

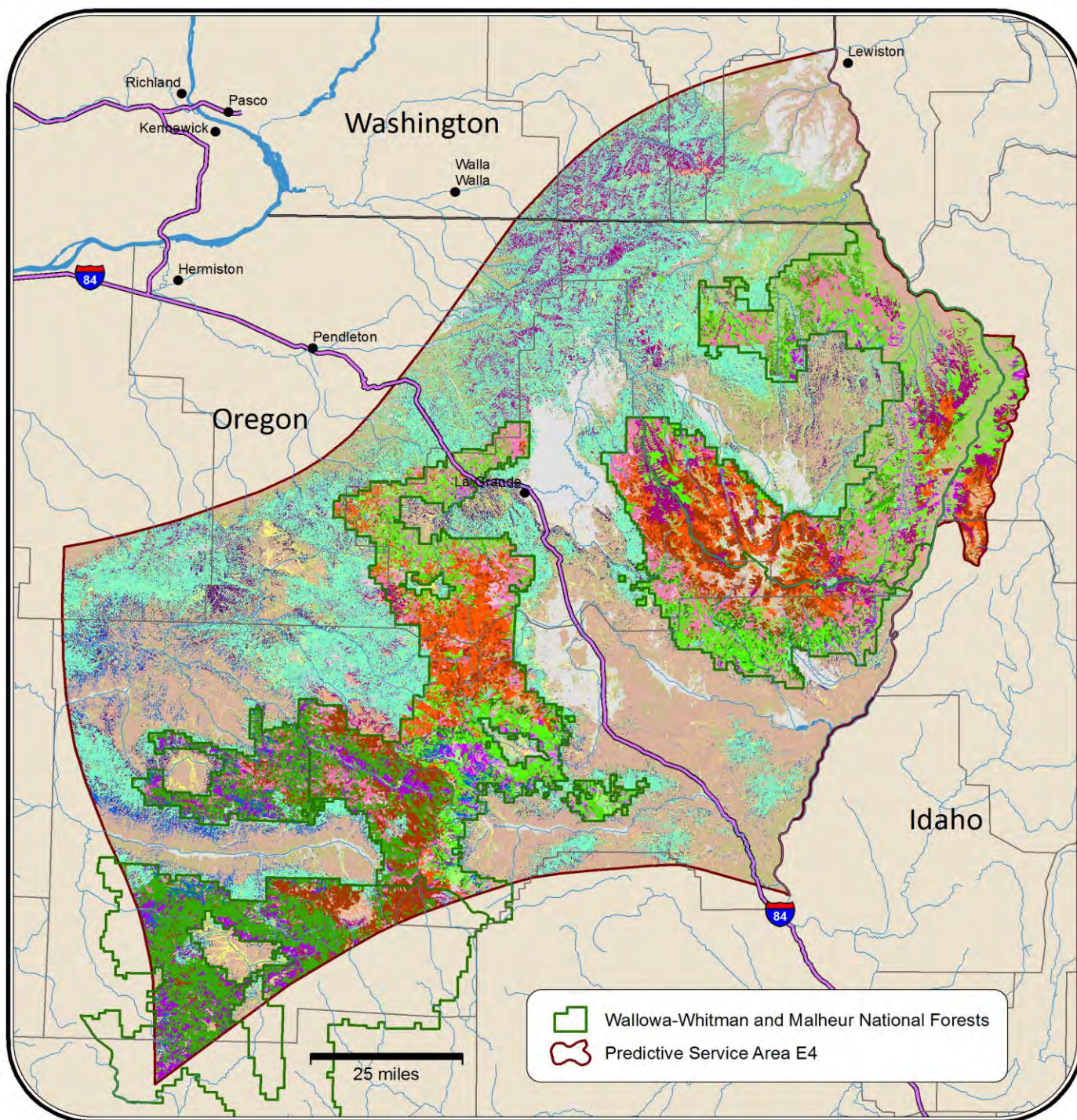


FCCS
Fuel Characteristic Classification System
Developed by the Fire and Environmental Research Applications Team



ERDC - Forest Service
Pacific Northwest Research Station
FERA
Forest Fuelbed Fuelbed Classification System
Fire and Environmental Research Applications Team
4800 R. 230th Street, Suite 201 - Seattle, WA 98148
206-533-2888 - www.fccs.com





- ### FCCS Fuelbeds
- Agriculture/Barren/Developed
 - Shrubland
 - Western juniper/ bunchgrass savannah
 - Grassland
 - Aspen
 - Lodgepole pine forest
 - Grand fir forest
 - Grand fir -- Douglas-fir Forest
 - Other forests
 - Douglas-fir 0-15 years
 - Douglas-fir 15-40 years
 - Douglas-fir 40-80 years
 - Douglas-fir 80-150 years
 - Douglas-fir >150 years
 - Douglas-fir/Ponderosa pine
 - Douglas-fir/Ceanothus forest
 - Subalpine forest 0-90 years
 - Subalpine forest >90 years
 - Other subalpine forests
 - Ponderosa pine savannah
 - Ponderosa pine 0-40 years
 - Ponderosa pine 40-80 years
 - Ponderosa pine > 80 years

Wallowa-Whitman and Malheur National Forests

Predictive Service Area E4

25 miles

How does FCCS translate a Fuelbed to Fire Behavior and Fire Effects?



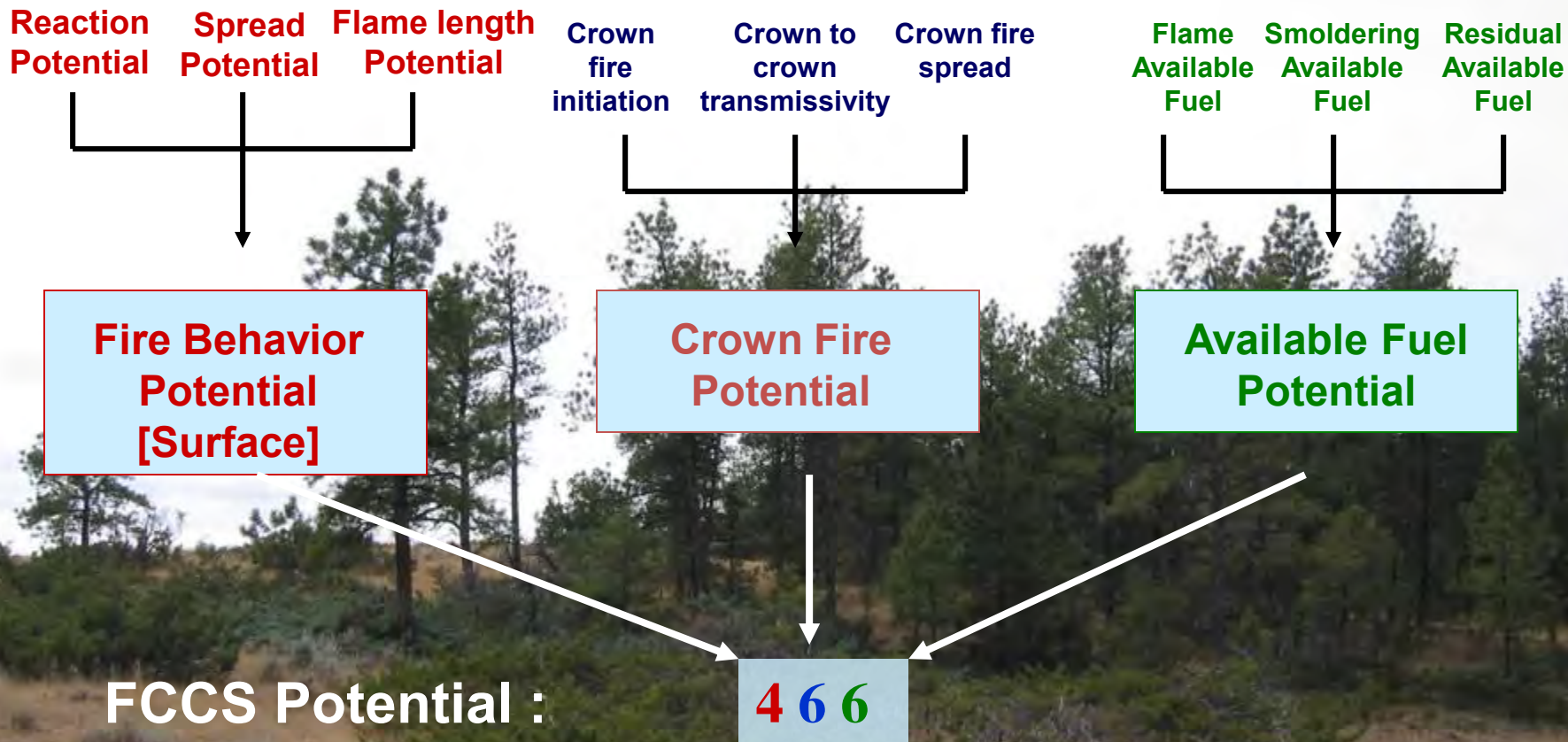
- 1) Fire Potentials ←
- 2) Fire Behavior Prediction
- 3) FCCS Fuelbed/Fuel Model Crosswalk

FCCS Fire Potentials

Capability for a fuelbed to support a surface fire and crown fire and to consume and smolder fuels



FCCS Fire Potentials Flow Chart



4 = modest surface fire (8 ft. flame, 4000 BTU/ft²-min)
6 = above average crowning potential (6 on scale of 10)
6 = above average (60 tons per acre consumed)



← **Ponderosa Pine**

4 3 5



Long Leaf Pine →

4 3 5





Eastside Pine prior to harvesting (2002) Strata - E2G (approx. 300+ Trees Per Ac.)

FCCS Fire Potential:
657



Eastside Pine after harvesting (2002) Strata - E3N (approx. 90-110 Trees Per Ac.)

FCCS Fire Potential:
213

- Removed 28.5 green tons/ac., which was 40% sawlogs and 60% chips and biomass
- Generated \$74,183.00 or \$124.67/ac. in revenues for the portion of the sale which is harvested
- The objectives were to develop a DFPZ and improve stand health and vigor.
- CASPO Prescription

How does FCCS translate a Fuelbed to Fire Behavior and Fire Effects?



1) Fire Potentials

2) Fire Behavior Prediction ←

3) FCCS Fuelbed/Fuel Model Crosswalk

Reformulated surface fire behavior equations calculates heat sink and source by shrub, grass, small woody, and litter components allowing the use of measured fuels!!

▪



Shrubs



Herbs



Small Woody



Litter

Reaction Intensity Equation

Rothermel (1972)

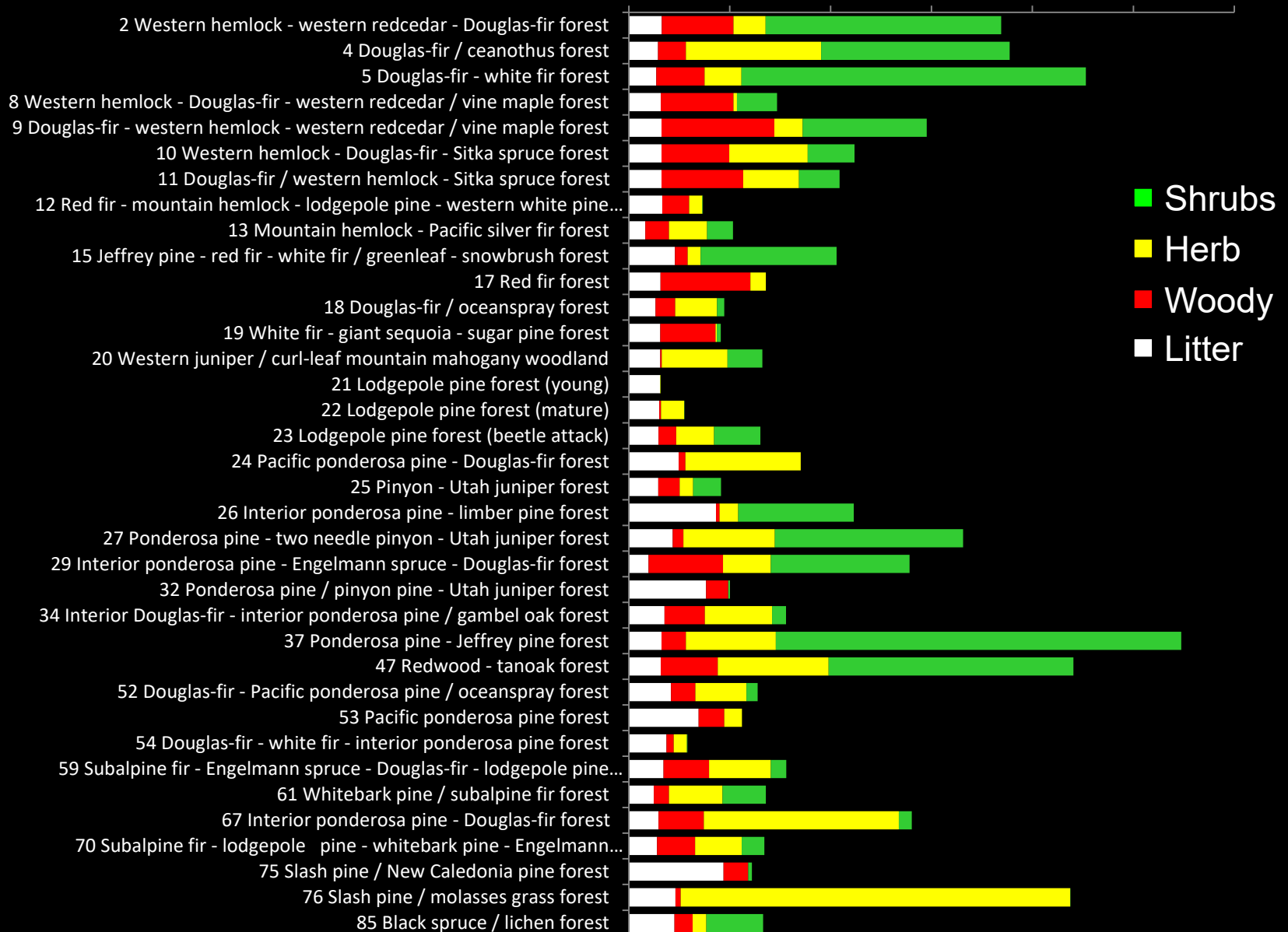
$$\text{Reaction Intensity } (I_R) = \Gamma' w_n h \eta_s \eta_m$$

FCCS

$$\text{Reaction Intensity } (I_R) = \sum \left[\underbrace{\Gamma'_{max} \eta_{\beta'}}_{\text{Efficiency}} \underbrace{w_n h \eta_s \eta_m}_{\text{Reactive load}} \right]$$

Shrubs
 Herb
 Woody
 LLM

Reaction Intensity (conifer forests)



How does FCCS translate a Fuelbed to Fire Behavior and Fire Effects?



1) Fire Potentials

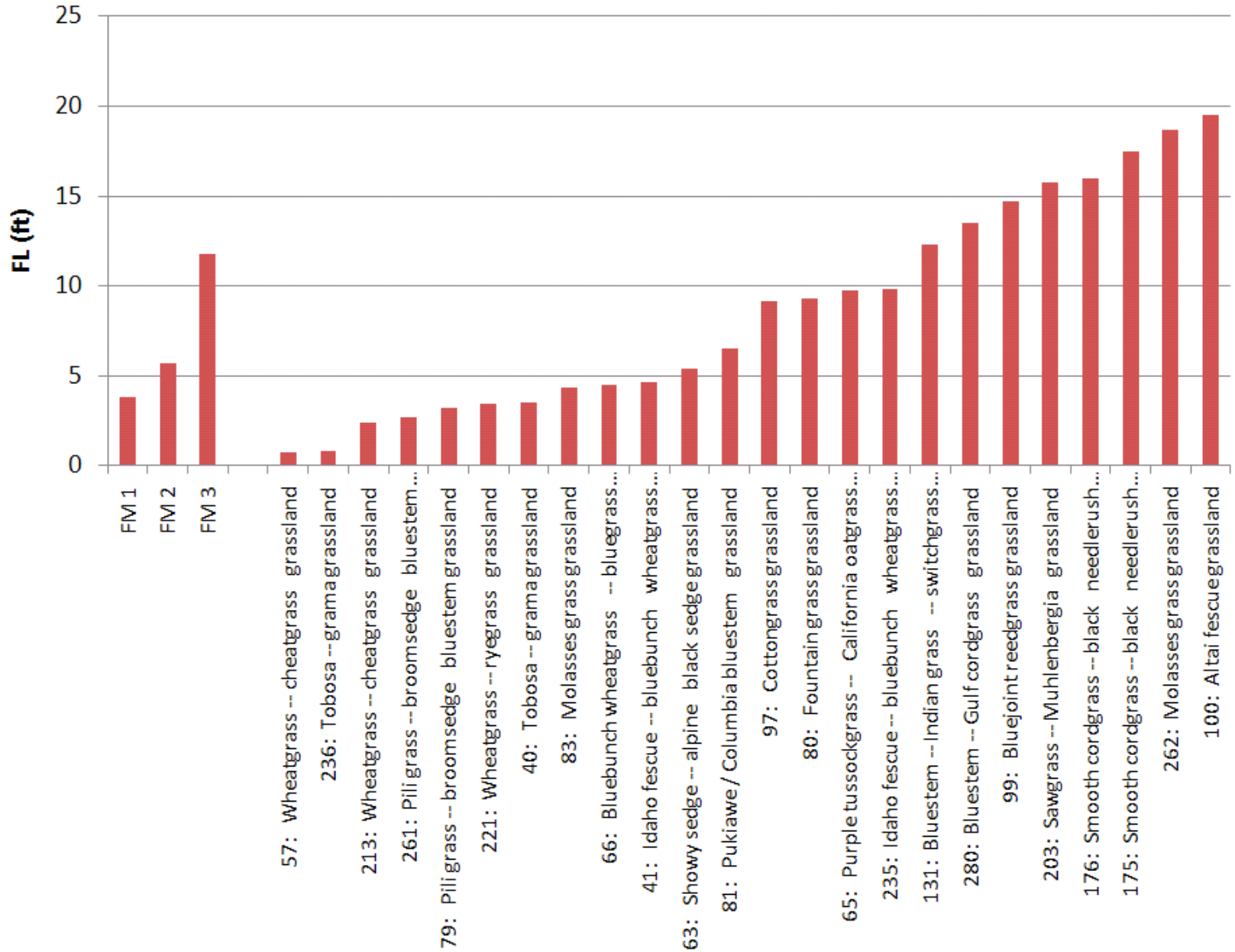
2) Fire Behavior Prediction

3) FCCS Fuelbed/Fuel Model Crosswalk

FCCS Fuelbed/Fire Behavior Crosswalk (suggested by NFC)

- FCCS reference and customized fuelbeds cross walked to 13 and 40 Fire Behavior Fuel Models
- Allows Farsite/Behave runs

Grassland fuelbeds vs original 13





United States Department of Agriculture
Forest Service

Pacific Northwest
Research Station

General Technical Report
PNW-GTR-887

October 2013

Fuel Characteristic Classification System Version 3.0: Technical Documentation

Susan J. Prichard, David V. Sandberg, Roger D. Ottmar,
Ellen Eberhardt, Anne Andreu, Paige Eagle, and Kjell Swedin



United States Department of Agriculture

Fuel Characteristic Classification System (FCCS) Field Sampling and Fuelbed Development Guide

Susan J. Prichard, Anne G. Andreu, Roger D. Ottmar, and Ellen Eberhardt



Forest
Service

Pacific Northwest
Research Station

General Technical Report
PNW-GTR-972

February
2019

Validation

A photograph of a forest fire. In the center, a large fire with bright orange and yellow flames is burning, with thick white and grey smoke rising from it. The fire is surrounded by trees, some of which are charred or have lost their leaves. The background shows more trees and a hazy sky. The overall scene is dramatic and somewhat somber.

- Anecdotal evidence
 - Workshops
 - Managers
 - Projects
- Range within Rothermel outputs
- Other data comparison (future)

CONSUME

Fuel & Fire Tools (FFT)

Fuel & Fire Tools

An Integration of FCCS, Consume,
FEPS, The Pile Calculator,
and The Digital Photo Series



Clearcut
Western Washington



USDA - Forest Service
Pacific Northwest Research Station
FERA Pacific Wildland Fire Sciences Laboratory
Fire and Environmental Research Applications Team
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Fuel & Fire Tools

An Integration of FCCS, Consume,
FEPS, The Pile Calculator,
and The Digital Photo Series



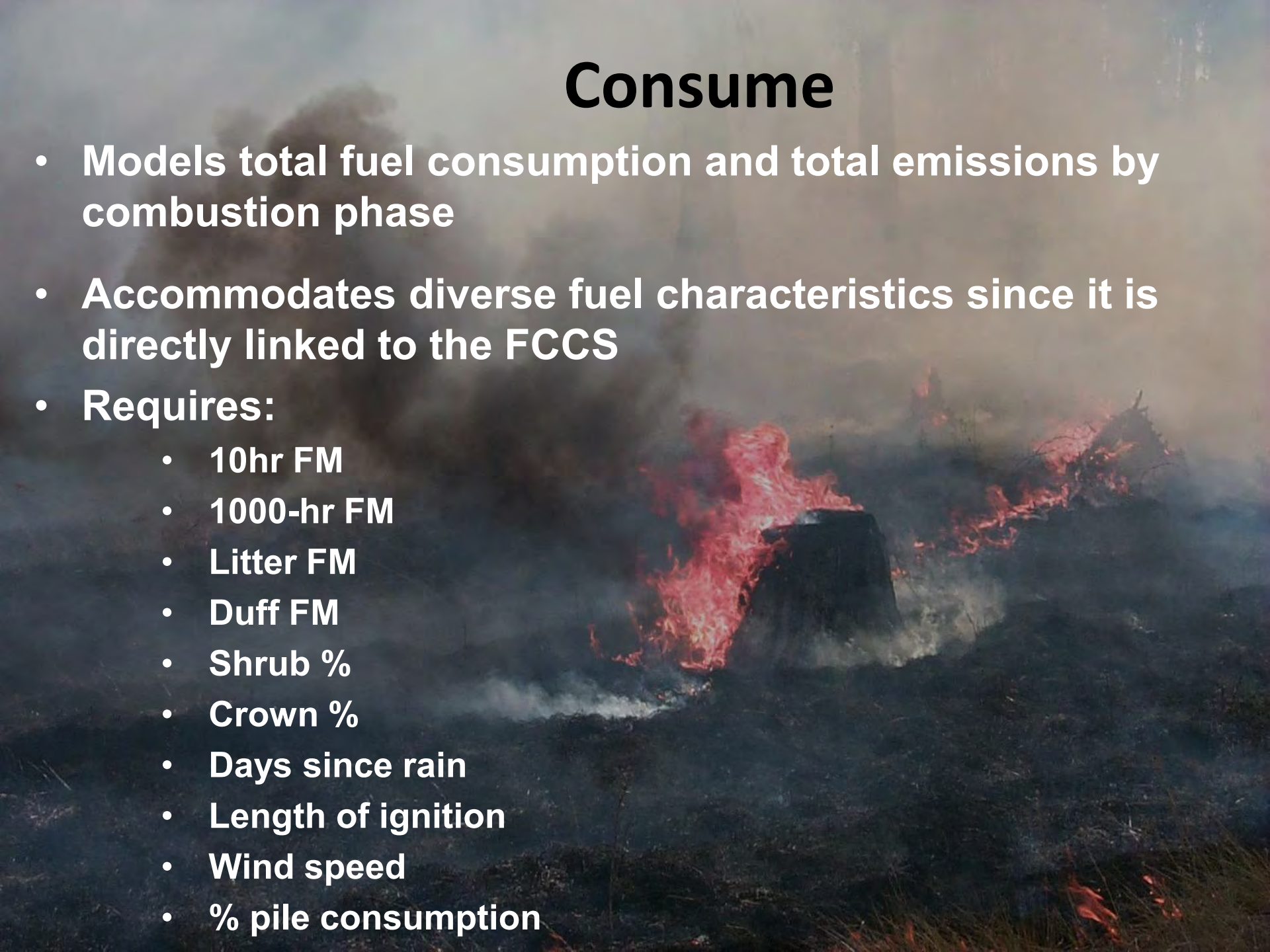
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Continue

Consume

- Models total fuel consumption and total emissions by combustion phase
 - Accommodates diverse fuel characteristics since it is directly linked to the FCCS
 - Requires:
 - 10hr FM
 - 1000-hr FM
 - Litter FM
 - Duff FM
 - Shrub %
 - Crown %
 - Days since rain
 - Length of ignition
 - Wind speed
 - % pile consumption
- 
- A photograph of a forest fire. The scene is dominated by thick, dark grey smoke that fills the upper half of the frame. In the center and right, bright orange and red flames are visible, consuming what appears to be a tree stump or a pile of wood. The ground in the foreground is dark and charred, with some sparse, dry vegetation. The overall atmosphere is hazy and smoky.

Fire Emission Production Simulator

- Fuel consumption rate
- Emission rate
- Heat release rate
- Required for dispersion modeling
- Requires:
 - temperature
 - relative humidity
 - mid-flame and transport wind speed
 - ignition start and stop
 - fire shape



FFT Current and Next Steps

- **Add additional FCCS fuelbeds**
- **Update fuel consumption equations**
- **Update emission factors**
- **Continue evaluating with data sets**

July 21,
Manage

Black Area

Land managers, Satellite

Predicting Smoke Impacts

Fuel Loading

FCCS, Photo series, FFT, LANDFIRE

Fuel Consumption

Consume, FFT
FOFEM

Emission Factor

Missoula Fire Lab, FFT

Emission Production

FEPS, FFT

Dispersion/Concentration

BlueSky

FFT

November 20, 2008 1:17 PM

Prescribed burn

An aerial photograph showing a large, billowing plume of white and grey smoke rising from a forested area in the distance. The smoke spreads across the sky, partially obscuring the blue and white clouds. The foreground and middle ground consist of dense, dark green forest with some cleared areas and roads visible. The overall scene is a prescribed burn in progress.

Questions?