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FIRE POTENTIAL RATING FOR WILDLAND FUELBEDS

Dr. David V. Sandberg*
USDA Forest Service, Pacific Northwest Research Station, Corvallis, Oregon

The Fuelbed Characteristic Classification System, or FCCS (Sandberg and others 2001) is a systematic catalog of inherent physical properties of any wildland fuelbed. FCCS is designed to provide the best possible fuel estimates and potential fire parameters based on as much or as little site-specific information as is available. The detailed fuel estimates are needed to support fire hazard assessments and fuel treatment decisions, as well as other research initiatives or assessments such as biomass emission inventories and carbon sequestration. FCCS will provide these detailed estimates based on either *specific fuel data* (types of fuel and their relative abundance) or *general site data* that are available for broader areas (such as Ecoregion Division, vegetation form, cover type, or other data obtained from remote sensing, forest inventories, or models). The system will also accept a mixture of both types of data.

FCCS is comprised of:

1. A large database of physical parameters that describe the size, abundance, physical character, and arrangement of the several dozen components that comprise a wildland fuelbed; compartmentalized by vertical position from forest canopy, shrub vegetation, low vegetation, woody fuels, litter, and moss/duff strata. The prototype FCCS database includes 200+ fuelbeds common to North America, and a process has been established to add several tens of thousands more fuelbeds in the next several years.

2. An expert system to interactively select a fuelbed from general site data and to adjust fuelbeds in the database based on specific site data or other information available to the user. This component of the system also calculates and summarizes fuelbed properties by vertical strata, and uses a set of look-up tables to assign properties based on vegetation species or physiognomic character.

3. Calculation of relative (normalized to a scale of 0-10) fuelbed fire potentials, i.e. the intrinsic capacity of a fuelbed for surface fire behavior, crowning potential, and fuel consumption. These potentials are calculated from the loading, heat content, bulk density, and characteristic thickness of fuel elements without consideration of moisture content or environmental conditions. Essentially, they represent the potential fire behavior and effects of an oven-dry fuelbed with no wind or slope influence.

FCCS calculates and reports nine fire potentials for every fuelbed, arranged in three categories:

A. **Fire behavior potential (FPR**), consisting of a user-defined combination of three component potentials, all patterned after the fire spread model by Rothermel (1972):

1. *Reaction potential (RP*) that represents the approximate reaction intensity (energy release per unit area per unit time) and is a function of fuel surface area per unit of ground surface, depth of the surface fuelbed stratum, heat of combustion, and a scaling factor based on flammability.

Two important adjustments were made that depart from Rothermel's model:

a. Rather than calculating a characteristic surface-to-volume ratio by weighing fuel loads in several size classes by their surface area, as described by Rothermel (1972), FCCS calculates the total fuel surface area on all size classes of fuels as a starting point for determining the optimum packing ratio of a fuelbed stratum. This parameter, the fuel area index (FAI), is the fuel surface area per unit ground surface area and is conceptually identical to the leaf area index used by ecologists. This results in a slightly different calculated optimum packing ratio that presumes that a constant ratio of airspace to unit fuel surface area within the fuelbed is optimal.

* *Corresponding author address*: David V. Sandberg, USDA Forest Service, 3200 SW Jefferson Way, Corvallis, OR 97331; e-mail: dsandberg@fs.fed.us

b. Litter, moss, and lichen fuel elements are considered a separate vertical stratum from other surface fuels by FCCS, rather than assuming that they are homogeneously distributed through the entire depth of the surface fuels as described by Rothermel (1972). FCCS calculates the reaction intensity from the more compact litter-moss-lichen stratum, then adds that energy to the energy released by other surface fuels.

2. *Spread potentia*l *(SP*) that is proportional to the no-wind rate of spread in surface fuels (distance per unit time), and is a function of Reaction Potential and the abundance of very fine (less than 1 mm diameter) fuels. Two important adjustments were made that depart from Rothermel's model:

a. The effective heating number, which is the proportion of fuel mass that must be raised to ignition temperature, is also based on FAI rather than characteristic surface to volume ratio. FCCS assumes that a shell approximately 1mm thick must be heated before ignition occurs. This leads to the second departure.

b. Very fine fuels (less than about 2mm thick) are assumed by FCCS to ignite more rapidly (i.e. with less energy input) than predicted by Rothermel (1972). We believe that Rothermel's equation overestimates the heat sink represented by very fine fuel elements.

3. *Flame length potential (FP),* proportional to fireline intensity or flame length and derived simply from the normalized product of RP and SP.

The user may define fire behavior potential (FPR) as any meaningful combination of RP, SP, and FP, scaled to a maximum value of 10. By default, the FCCS calculator will consider FPR to be equal to SP.

B. **Crown fire potential (CFP**) which is a rule-based ranking of crown fire potential based on admittedly poor scientific understanding of the factors that control torching and crowning, based on:

1. *Torching potential* (TP) is a heuristic that rates the potential for crown involvement based on the FP related to the physical gap distance between the surface and crown fuel strata.

2. *Dependent crown fire potential (DC*), a heuristic based on TP, canopy dimensions, and crown cover.

3. *Independent crown fire potential (IC)* is another heuristic similar to DC, but with higher thresholds of crown cover.

The user may define crown fire potential (CFP) as any meaningful combination of TP, DC, and IC, scaled to a maximum value of 10. By default, the FCCS calculator will consider CFP to be the maximum of TP/3, DC/1.5, or IC.

C. **Available fuel potential (AFP)**, which is simply a multiple of the total fuel loading of all fuel elements within a set depth from the surface of the fuel component, intended to approximate the combustible biomass under oven-dry moisture conditions in each of three stages of combustion:

1. *Flame available fuel (FA),* the sum of mass within one-half inch (12.7 mm) of the surface of the fuel element.

2. *Smoldering available fuel (SA),* the mass between ½ and 2 inches (51 mm) of a surface, and

3. *Residual available fuel (RA),* the mass between 2 and 4 inches (100mm) of a surface.

The user may define AFP as any meaningful combination of FA, SA, and RA, scaled to a maximum value of 10. By default, the FCCS calculator will consider AFP to be the sum of the three component potentials.

Fire potentials are a set of relative values that rate the intrinsic physical capacity of any wildland fuelbed to release energy, and to spread, crown, consume, and smolder under extremely dry conditions. They are intended to map fire hazard and to ease communication of the degree of fire hazard. They can also be used in conjunction with knowledge of environmental conditions to approximate fire behavior and effects (i.e. scaled downward to reflect fuel moisture conditions or scaled upwards to represent wind or slope.)

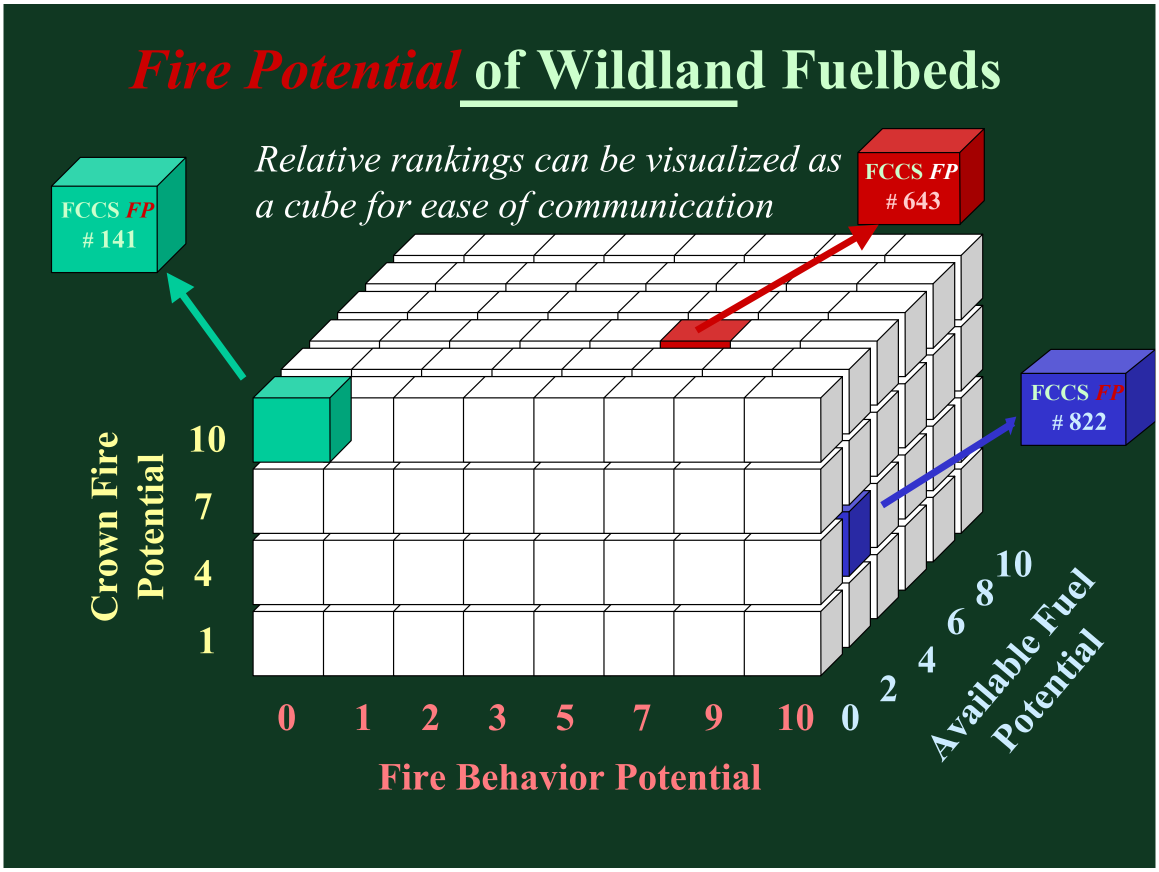

Figure 1. Fire Behavior Potential, Crown Fire Potential, and Available Fuel Potential are three relative rankings of the fire potential intrinsic to wildland fuelbeds. They represent the approximate fire behavior and biomass consumption of oven-dry fuelbeds under no-wind conditions. They are arranged in a cube for ease of communication. For example, a fuelbed with FCCS Fire Potential of 822 would have a very high potential for fire intensity or spread rate, low potential for crowning, and low potential for biomass consumption.

One way to visualize and communicate FCCS fire potentials is as a three-digit number that represents the relative potential along three axes of a cube (fig. 1). A user may rate a fuelbed (using a calculator embedded in FCCS software) according to its potential fire behavior (on a scale of one to ten), crowning potential, and available fuel, and compare that potential to any other fuelbed. For example, fire potential equal to #141 would represent a fuelbed with minimal potential for intense fire behavior, moderate potential for crowning, and minimal potential for biomass consumption. This unusual characteristic would probably represent a fuelbed with very low fuel surface area or highly compacted fuels, an abundance of fine ladder fuels, and low fuel loadings.

FCCS is intended to provide the capability to infer fuelbed characteristics from what is known about any fuelbed, including what is known explicitly combined with what is known by remote sensing or by inference from known biophysical circumstances. The fire potential calculation provides a flexible means of expressing any fuelbed as a function of its potential to produce fire behavior or effects. The intent is to provide an alternative to stylized fuel models that are more flexible and robust and that are easy to communicate.

Literature Cited

Rothermel, R.C. 1972: A mathematical model for predicting fire spread in wildland fuels. Research

Paper INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 40 p.

Sandberg, David V.; Ottmar, Roger D.; Cushon, Geoffrey H. 2001: Characterizing fuels in the 21st century. *International Journal of Wildland Fire*. **10**, 381-387.