Fire potential rating for wildland fuelbeds using the Fuel Characteristic Classification System[1]

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Abstract: The Fuel Characteristic Classification System (FCCS) is a systematic catalog of inherent physical properties of wildland fuelbeds that allows land managers, policy makers, and scientists to build and calculate fuel characteristics with complete or incomplete information. The FCCS is equipped with a set of equations to calculate the potential of any real-world or simulated fuelbed to spread fire across the surface and in the crowns, and consume fuels. FCCS fire potentials are a set of relative values that rate the intrinsic physical capacity of a wildland fuelbed to release energy and to spread, crown, consume, and smolder under known or benchmark weather and fuel moisture conditions. The FCCS reports eight component fire potentials for every fuelbed, arranged in three categories: surface fire behaviour (reaction intensity, spread rate, and flame length), crown fire potential (torching and active crown fire), and available fuel potential (flaming, smouldering, and residual smouldering). FCCS fire potentials may be used to classify or compare fuelbeds that differ because of location, structure, passage of time, or management action, based on expected fire behavior or effect outcomes. As a classification tool, they are offered as an objective alternative to categorizing bulk properties of fuelbeds or stylized model inputs.

Résumé : Le système de classification des caractéristiques des combustibles (SCCC) est un recueil systématique des propriétés physiques inhérentes des couches de combustibles en milieu naturel qui permet aux aménagistes du territoire, aux stratèges et aux scientifiques d'élaborer et de calculer les caractéristiques des combustibles avec une information complète ou incomplète. Le SCCC est doté d'un ensemble d'équations permettant de calculer la possibilité que n'importe quelle couche de combustibles, réelle ou simulée, propage le feu en surface ou dans les cimes et consume des combustibles. Les potentiels de feu du SCCC sont constitués d'un ensemble de valeurs relatives qui évaluent la capacité physique intrinsèque d'une couche de combustibles en milieu naturel de dégager de l'énergie et de se propager, d'atteindre les cimes, de consumer et de couver dans des conditions de température et d'humidité des combustibles connues ou fixées comme repères. Le SCCC rapporte huit composantes des potentiels de feu pour chaque couche de combustibles, organisées en trois catégories : comportement du feu en surface (intensité de la réaction, taux de propagation et hauteur de flamme), possibilité de feu de cimes (flambée en chandelle et feu de cimes dépendant) et le potentiel des combustibles disponibles (production de flammes, combustion lente et combustion lente résiduelle). Les potentiels de feu du SCCC peuvent être utilisés pour classer ou comparer des couches de combustibles qui diffèrent à cause de leur localisation, de leur structure, du temps écoulé ou des interventions d'aménagement sur la base du comportement prévu du feu ou de l'effet des résultats. Comme outil de classification, ils sont proposés à titre de solution de rechange objective au classement par catégorie des propriétés générales des couches de combustibles ou aux intrants simplifiés pour la modélisation.

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Introduction

Wildland fuels have historically been classified by a number of systems designed to rate their potential fire behaviour as a basis for fire management planning (Sandberg et al. 2001). The primary focus of fuel classification has been on rating the potential rate of spread or rate of perimeter increase from an initiating fire so that initial attack response time could be designed to contain the fire at a reasonable size (Show and Kotok 1930). The second consideration has been how difficult a fire will be to suppress, such as by classifying "resistance to control" (Hornby 1936). Rate of spread and resistance to control under "average worst" conditions were assigned a descriptive class — "low, medium, high, or extreme." Barrows (1951) later added "flash" as the fifth class to account for rates of spread in grass and logging slash. These early classifications were widely applied and somewhat useful, but were judged as arbitrary and insensitive to the wide variability in fire hazard within cover types, especially where natural or human change agents had occurred, and did not consider crowning or other severe fire behavior (Brown and Davis 1973).

In the past 30 years, many fire management decision support systems in the United States have been based on Rothermel's (1972) fire spread model, a mathematical model applicable to initiating fires in uniform homogeneous surface fuels to classify fuels by rate of spread and flame

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length, the latter a measure of resistance to control. Stylized fuel models (Albini 1976; Anderson 1982) were developed to provide standardized numerical inputs to the spread model. These fuel models, and those developed for the related National Fire Danger Rating System (Deeming et al. 1977) have become the US national norm for classifying and mapping fuel characteristics. Fuel models were not designed to be correlated with actual fuel loadings, depths, vegetation cover, remote-sensing signatures, modelled ecosystem dynamics, or biomass consumption, but have been widely used to infer those properties.

Resource managers need to assess and map fuelbed characteristics for many reasons other than estimating flame length and surface rate of spread from wildfires. Fire use to achieve ecological benefits and reduce fire hazard requires the ability to predict fire effects. Smoke management and carbon accounting are increasingly important factors in considering fire management options. The current emphasis on fuels management to reduce the incidence of large, severe fires requires quantitative metrics of fuel management accomplishment. For all of these reasons, Ottmar et al. (2007) developed the Fuel Characteristic Classification System (FCCS) to more precisely and uniformly catalogue and map the realistic and complex characteristics of fuelbeds as input to any number of fire behaviour and effects models and decision support systems.

In this paper, we develop an approach to rating and classifying any fuelbed, no matter how complex and at any scale, based solely on the intrinsic physical and chemical fuelbed characteristics of the fuelbed. We provide examples of being able to classify fuelbeds on the basis of potential fire behaviour or fire effects, both quantitatively and repeatably, based on direct measurement or modelled fuelbed characteristics. By rating fuelbeds objectively, the user of FCCS is able to classify fuelbeds according to the fire behaviour or effect of interest at any scale or precision.

Current FCCS fire potentials are a set of relative values or indices that rate the intrinsic physical capacity of a wildland fuelbed to release energy and to spread, crown, consume, and smolder under a known or benchmark set of wind speed and fuel moisture conditions. They are intended for use in mapping fire hazard, categorizing fuelbeds on the basis of predicted fire behaviour, predicting and measuring the effects of fuel treatment, and to ease communication of the degree of hazard.

Current FCCS fire potentials

The FCCS calculates and reports eight fire potentials for every fuelbed, arranged in three categories (Fig. 1). The surface fire behavior potential (FBP) uses the concepts and basic spread equations that form the basis of the Rothermel (1972) spread model that is in widespread use for fire management decision support in the United States, but uses a model reformulation (Sandberg et al. 2007) that allows inventoried or simulated real-world fuelbed properties as direct input. Crown fire potential (CFP) derives from application of Van Wagner (1977), Alexander (1998), and Scott and Reinhardt (2001), but utilizes a conceptual model by Schaaf et al. (2007) that is more flexible with regard to fuelbed characteristics and canopy structure. The conceptual crown fire model retains the limiting assumption that crown fire initiation occurs only as a result of surface fire energy release from the propagating front. Available fuel potential (AFP) represents the mass of fuel present within the outside shell of layers of surface, ground, and canopy fuel elements that is potentially combustible under extremely dry conditions. All FCCS fire potentials use a common set of fuel characteristics, known as FCCS fuelbeds (Riccardi et al. 2007) as input.

One way to visualize and communicate FCCS fire potentials is as a three-digit number that represents the intrinsic potential of a fuelbed to create fire behaviour and effects (Fig. 1). A user may rate a fuelbed (using the calculator embedded in the FCCS software) according to its potential surface fire behaviour, crowning, and available fuel, and compare that potential with another fuelbed. For example, an FCCS fire potential of 469 would represent a fuelbed with a modest surface fire potential, above-average crown fire potential, and extreme potential for biomass consumption.

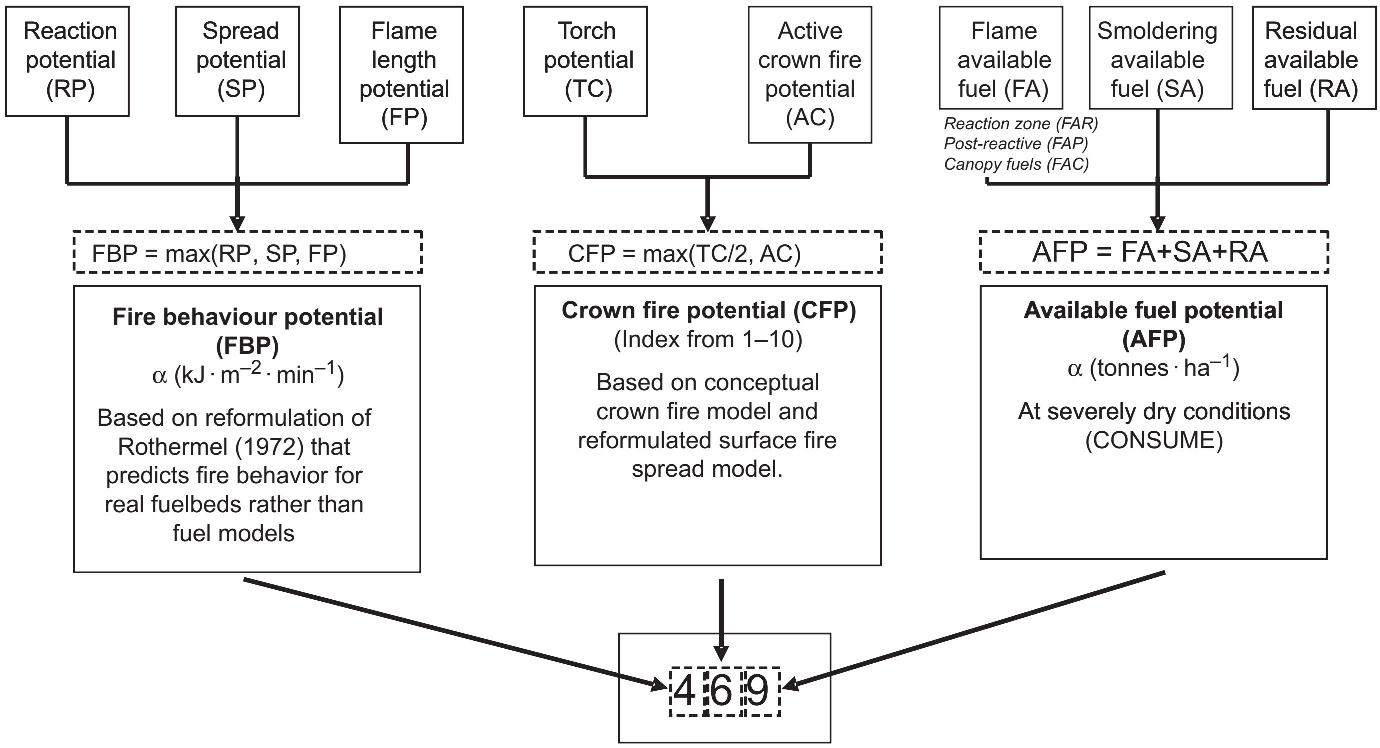
Relative indices of fire behaviour and effects can be useful for mapping and categorizing fuelbeds, but other uses depend on predictions with real units. The FCCS offers the option of inputting fuel moisture contents and wind speed values to obtain predictions of fire behaviour and fuel consumption at those conditions. In so doing, the user implicitly accepts the algorithms that describe the effect of moisture and wind speed on surface fire behaviour (Rothermel 1972; Wilson 1990; Sandberg et al. 2007), crown fire behaviour (Schaaf et al. 2007), and fuel consumption. We anticipate that these algorithms will be improved over time.

FCCS surface fire behaviour potential

FCCS FBP consists of a predefined combination of three component potentials, all patterned on a fire spread model derived from the one-dimensional spread model by Rothermel (1972), as modified by Albini (1976), currently in widespread use. Rothermel's model serves in many applications as the basis for decision support for planning and operations by fire managers, so every attempt was made to base the three components of FBP on the semiempirical equations and experimental results of Rothermel (1972) and Frandsen (1973), aided by the observations of subsequent researchers (e.g., Wilson 1990; Catchpole et al. 1998).

Sandberg et al. (2007) reformulated the Rothermel (1972) fire spread model to allow direct input of inventoried fuelbed characteristics by rearranging the terms to separate fuelbed characteristics from environmental influences. The order of calculation is to first compute the potential surface fire behavior for a fuelbed under ideal environmental conditions, that is, when there is no damping effect of moisture or mineral content and when midflame wind speed is 1.8 $m \cdot s^{-1}$. This "surface fire behaviour potential" calculation is affected solely by physical and chemical characteristics of the fuelbed, their arrangement, and composition. The values are meaningful only as an index, although they are dimensional. Scaled to relative values of 0–10, however, they provide an objective and reproducible means to compare fuelbeds that have different physical characteristics. The scaling factors used are simply the maximum value, divided by 10, of spread

Fig. 1. Fuel Characteristic Classification System (FCCS) fire potentials are expressed as a three-digit number representing the intrinsic capacity of a fuelbed to produce fire behaviour and fire effects that may be parsed into as many as 12 components. There are three categories of FCCS fire potentials (surface fire behavior potential (FBP), crown fire potential (CFP), and available fuel potential (AFP)), each of which combine component FCCS fire potentials (e.g., FBP combines reaction potential (RP), spread potential (SP), and flame length potential (FP)).



rate, intensity, and flame length calculated for an initial set of fuelbed characteristics from an independent data set of 216 prototype FCCS fuelbeds provided by Riccardi et al. (2007).

Early releases of the FCCS (versions 1.0 and 1.1) arbitrarily calculate FBP as the maximum of its three component potentials, scaled to values of 0–10. We realize that other combinations may be useful to some users, who may want to combine the component potentials in other ways to serve local needs. For example, some managers may wish to rate fuelbeds simply on flame length alone, others, on reaction intensity and spread rate. If fire managers or other users request a more useful combination of these components as a standard index of fire hazard, the initial FBP can be replaced with the new index.

FBP component 1

Reaction potential (RP) represents reaction intensity ($kW \cdot m^{-2}$) and is a function of the reactive volume of fuels per unit of ground surface, depth of the surface fuelbed strata, heat of combustion, and a scaling factor.

FBP component 2

Spread potential (SP), which is proportional to the rate of spread ($m \cdot min^{-1}$) in surface fuels, and is a function of reaction intensity, propagating energy flux, the heat sink calculated for the unburned fuels in advance of the spreading flame, and a scaling factor.

FBP component 3

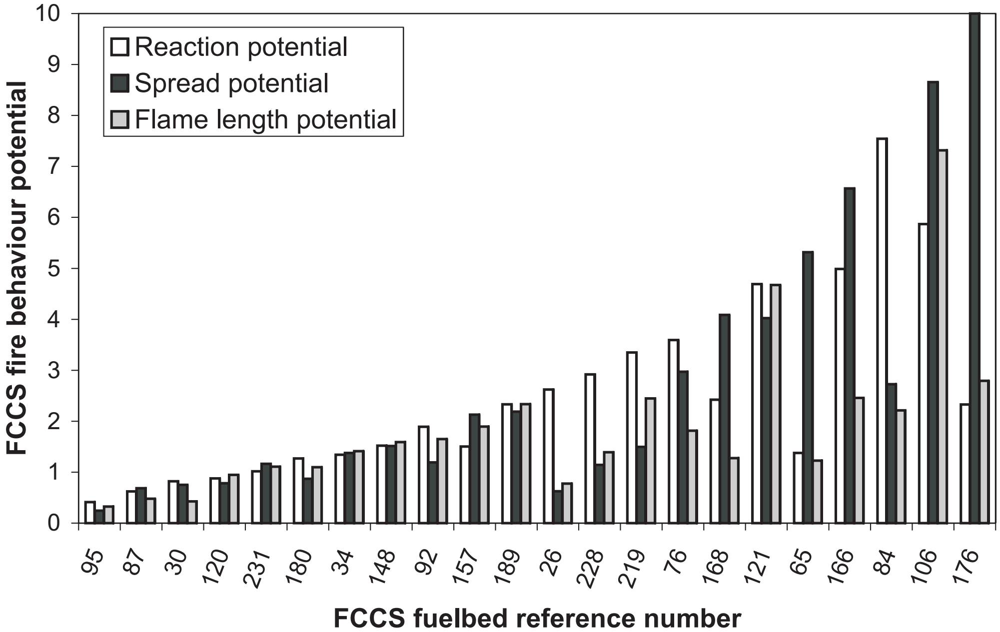
Flame length potential (FP), which is proportional to the predicted flame length (m), and is derived from the product of reaction intensity, rate of spread, and flame residence time such as in Byram (1959) and Albini (1976).

The FCCS includes 216 FCCS fuelbeds that are sets of physical characteristics of fuel types important to fire managers in the United States. These fuelbeds will be augmented in the future by additional fuelbeds, including many defined by users. We have calculated FCCS fire potentials for all current FCCS fuelbeds, with examples illustrated in Fig. 2. Unadjusted FCCS predictions of reaction intensity, spread rate, and flame length span a similar range of values as model outputs from BehavePlus (Andrews et al. 2005) applied to fire behavior fuel models except that BehavePlus predicts higher spread rates in shrub-dominated fuel models (Sandberg et al. 2007).

FCCS crown fire potential

FCCS CFP is a ranking of crown fire potential based on whether or not the energy supplied by a surface fuelbed layer, as described by Sandberg et al. (2007), is sufficient to ignite and sustain fire spread in the canopy, as described by Schaaf et al. (2007). Early releases of FCCS calculate CFP by comparing the FCCS torching potential (TC) with the FCCS active crown fire potential (AC) such that $\mathrm{CFP} = \max\left(\frac{\mathrm{TC}}{2}, \mathrm{AC}\right)$. This expression of the relative importance of TC and AC is arbitrary. If users request a more useful combination of these components (such as using TC alone) as a standard index of crown fire potential, it can be replaced with a revised index in future FCCS versions. It is also likely that additional or revised indices will be added to

Fig. 2. Fuel Characteristic Classification System (FCCS) reaction potential, spread potential, and flame length potential for randomly selected FCCS fuelbeds, sorted from the lowest to highest surface fire behaviour potential. The component potentials range from 0 to 10, scaled such that the highest rated fuelbed from the family of 216 fuelbeds received a value of 10. FCCS fuelbed 26, interior ponderosa pine – limber pine forest; fuelbed 30, turbinella oak – mountain mahogany shrubland; fuelbed 34, Douglas-fir – interior ponderosa pine – Gambel oak forest; fuelbed 65, purple tussockgrass – California oatgrass grassland; fuelbed 76, slash pine – molassas grass forest; fuelbed 84, Ohio – Broomsedge bluestem savanna; fuelbed 87, black spruce – feathermoss forest; fuelbed 92, aspen – paper birch – white spruce – black spruce; fuelbed 95, willow – alder shrubland; fuelbed 106, red spruce – balsam fir forest; fuelbed 120, oak – pine – mountain laurel forest; fuelbed 121, oak – pine – mountain laurel forest; fuelbed 148, jack pine forest; fuelbed 157, loblolly pine – shortleaf pine – mixed hardwoods forest; fuelbed 166, longleaf pine – three-awned grass – pitcher plant savanna; fuelbed 168, little gallberry – fetterbush shrubland; fuelbed 176, smooth cordgrass – black needlerush grassland; fuelbed 180, red maple – oak – hickory – sweetgum forest; fuelbed 189, sand pine – oak forest; fuelbed 219, ponderosa pine – white fir – trembling aspen forest; fuelbed 228, interior ponderosa pine – limber pine forest; and fuelbed 231, Gambel oak – juniper – ponderosa pine forest.



future FCCS versions as the science and applications mature.

The FCCS CFP is based on an updated semiempirical model that describes crown fire initiation and propagation in vegetative canopies. It is based on the work by Van Wagner (1977) and Rothermel (1991), but contains some new concepts for modeling crown fire behaviour derived from the reformulated Rothermel (1972) surface fire modeling concepts proposed by Sandberg et al. (2007). This modeling framework (Schaaf et al. 2007) is conceptual in nature. To date, it has been tested against only one independent data set, although more such studies are planned.

The general form of the FCCS CFP equation is

$$[1] \qquad \text{CFP} = f(I_{\text{C}}, T_{\text{C}}, R_{\text{C}}) = \max\left(\frac{\text{TC}}{2}, \text{AC}\right)$$

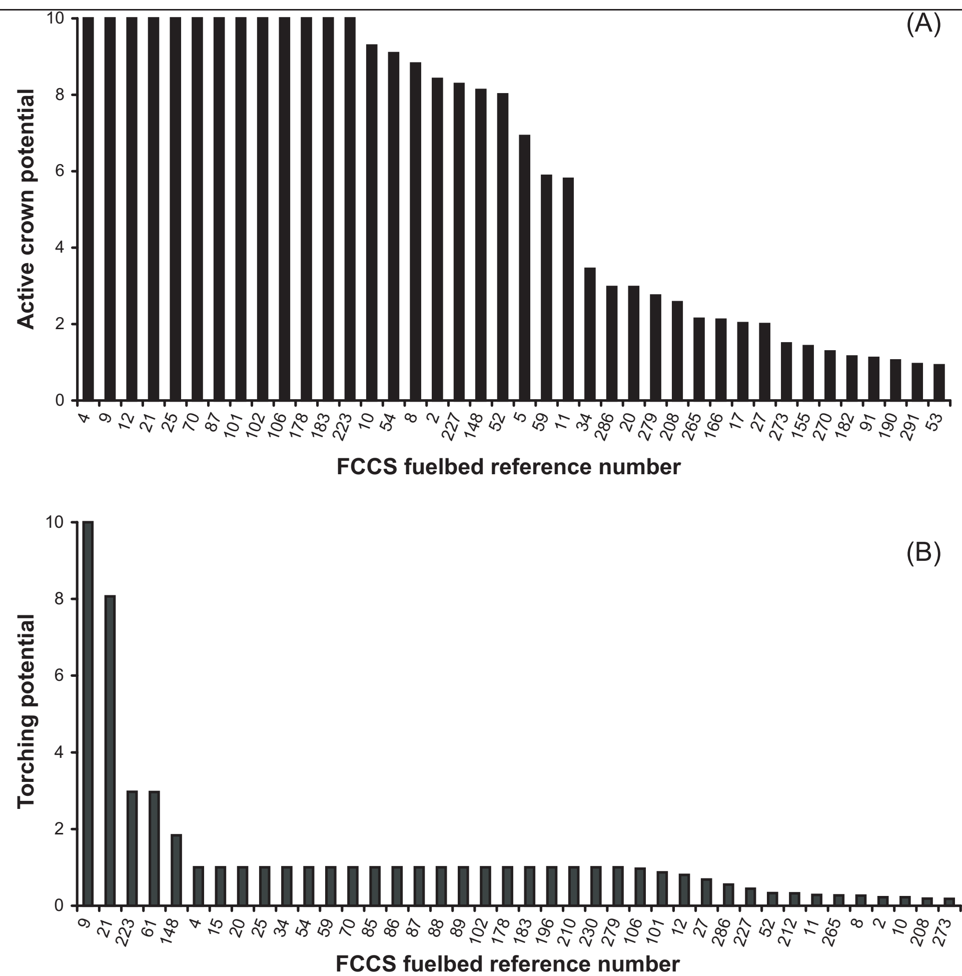
where I_{C} is the crown fire initiation term (dimensionless) and is the ratio of the surface fireline intensity to the critical surface fireline intensity required to ignite the lower canopy fuels. Values typically range from 0 to 10 or more; T_{C} is the crown-to-crown transmissivity term (dimensionless) and is a measure of the likelihood that a crown fire, once initiated, will actively propagate through the canopy. Values range from 0 to 1; R_{C} is the crown fire spread rate term ($\text{m}\cdot\text{min}^{-1}$) and is a measure of the likelihood that an active crown fire will grow into a large, resource intensive fire. Values range from 1 to >100 $\text{m}\cdot\text{min}^{-1}$; TC is also known as CFP component potential 1 and is a dimensionless measure of the potential for a surface fire to spread into the canopy as single- or group-tree torching. TC is calculated on the basis of the scaled (i.e., 0–10) I_{C}; and AC is also known as CFP component potential 2 and is a dimensionless measure of the potential for a surface fire to spread into and actively propagate through the canopy. AC is calculated on the basis of the scaled (i.e., 0–10) product of the I_{C}, T_{C}, and R_{C} terms.

Figure 3 provides an example of the CFP ratings for a selection of FCCS fuelbeds; in this case, fuelbeds found in boreal regions. We have not compared these ratings with results from any other crown fire prediction systems.

The past 40 years of fire research and observations have produced a significant body of literature on crown fires ranging from observations, to descriptions of fire types, to heuristic keys for rating crown fire potential, to the partial development of mathematical models for predicting crown fire behavior. However, these have been limited to localized forest conditions and admittedly inadequate to serve as a universally applied crown fire model. Crown fire prediction that depends on continued energy input from a spreading line fire under a continuous one-story canopy is offered by Van Wagner (1993), Scott and Reinhardt (2001), Cruz et al. (2003), and Cruz et al. (2006*a*, 2006*b*).

The identification of wind speed thresholds for passive

Fig. 3. Examples of Fuel Characteristic Classification System (FCCS) crown fire potentials: (A) torching potential (TC) and (B) active crown fire potential (AC). Each is computed as an index value ranging from 0 to 10. Each index has been computed for all FCCS fuelbeds. This figure displays only FCCS conifer forest fuelbeds. FCCS fuelbed 2, western hemlock – western redcedar – Douglas-fir forest; fuelbed 4, Douglas-fir – *Ceanothus* forest, fuelbed 5, Douglas-fir – white fir forest; fuelbed 8, western hemlock – Douglas-fir – western redcedar –vine maple forest; fuelbed 9, Douglas-fir – western hemlock – western redcedar – vine maple forest; fuelbed 10, western hemlock – Douglas-fir – Sitka spruce forest; fuelbed 11, Douglas-fir – western hemlock – Sitka spruce forest; fuelbed 12, Douglas-fir – western hemlock – Sitka spruce forest; fuelbed 15, Jeffrey pine – red fir – white fir – greenleaf manzanita – snowbrush forest; fuelbed 17, red fir forest; fuelbed 20, western juniper – mountain mahogany woodland; fuelbed 21, lodgepole pine forest; fuelbed 25, pinyon – juniper forest; fuelbed 27, ponderosa pine – two-needle pinyon – Utah juniper forest; fuelbed 34, interior Douglas-fir – interior ponderosa pine – Gambel oak forest; fuelbed 52, Douglas-fir – Pacific ponderosa pine – Oceanspray forest; fuelbed 53, Pacific ponderosa pine forest; fuelbed 54, Douglas-fir – white fir – interior ponderosa pine forest; fuelbed 59, subalpine fir – Engelmann spruce – Douglas-fir – lodgepole pine forest; fuelbed 61 , whitebark pine – subalpine fir forest; fuelbed 70, subalpine fir – lodgepole pine – whitebark pine – Engelmann spruce forest; fuelbed 85, black spruce – lichen forest; fuelbed 86, black spruce – feathermoss forest; fuelbed 87, black spruce – feathermoss forest; fuelbed 89, black spruce –sheathed cottonsedge woodland; fuelbed 91, white spruce – prickly rose forest; fuelbed 101, white spruce forest; fuelbed 102, white spruce forest; fuelbed 106, red spruce – balsam fir forest; fuelbed 148, jack pine forest; fuelbed 155, red spruce – balsam fir forest; fuelbed 166, longleaf pine – three-awned grass – pitcher plant savanna; fuelbed 178, loblolly pine – shortleaf pine forest; fuelbed 182, longleaf pine – slash pine – saw palmetto –gallberry forest; fuelbed 183, loblolly pine – shortleaf pine forest; fuelbed 190, slash pine – longleaf pine – gallberry forest; fuelbed 196, loblolly pine – bluestem forest; fuelbed 208, Ggrand fir – Douglas-fir forest; fuelbed 210, pinyon – juniper forest; fuelbed 212, Pacific ponderosa pine forest; fuelbed 223, Douglas-fir – white fir – interior ponderosa pine forest; fuelbed 227, white fir forest; fuelbed 230, pinyon – juniper forest; fuelbed 265, balsan fir – white spruce – mixed hardwoods forest; fuelbed 270, red spruce – Fraser fir – rhododendron forest; fuelbed 273 , Engelmann spruce – Douglas-fir – white fir – interior ponderosa pine forest; fuelbed 279, black spruce – northern white cedar – larch forest; fuelbed 286, interior ponderosa pine – limber pine forest; and fuelbed 291, longleaf pine – slash pine – saw palmetto forest.



and active crown fires by Scott and Reinhardt (2001) based on stylized fuel models and Rothermel's (1972) surface flame length predictions are especially useful to managers within the limitations of current knowledge. Additional refinements of crown fire modeling and theory have been advanced by Cruz et al. (2005) and by Butler et al. (2004). A series of experimental crown fires were completed during the International Crown Fire Modelling Experiment in Canada (Stocks et al. 2004), which greatly contributed to an improved understanding of this phenomenon. They compared observed crown fire spread rates with predictions from a number of crown fire prediction models. This comparison indicated that a number of operationally used North American models underpredicted observed crown fire spread rates. There also remains a crown fire heuristic rating by Fahnestock (1970) that focuses only on crown structure and ladder fuels without considering energy needs.

Despite recent advances, there is still a pressing need for decision support tools that can assist fuel and fire managers in identifying and prioritizing fuelbeds on the basis of their crown fire potential. Little decision support is available for assessing crown fire behavior within complex fuelbeds, especially nontimber fuelbeds, or for assessing the conditions under which postfrontal torching fires or independent crown fires occur. Our understanding of flammability limits and the processes of heat transfer from and within forest canopies is inadequate to provide a complete modelling system relevant for many of the environments that experience crown fires.

Collectively, these studies have shown that the potential for crown fire occurrence does not depend on any single element of the fuel complex or on any single element in the fire weather environment. Rather, crown fires result from various combinations of factors in the fuel, weather, and topography. Important factors include surface fire intensity, canopy closure, crown density, presence or absence of ladder fuels, height to the base of the combustible crown, crown foliar moisture content, and wind speed. This understanding is the foundation for the framework advanced by Schaaf et al. (2007).

FCCS available fuel potential

FCCS AFP is a multiple of the total fuel loading of all fuelbed components within a defined depth from the surface of the fuel component, expressed in units of 10 tonnes·ha^{-1}. AFP is intended to approximate the combustible biomass under very dry conditions in each of three stages of combustion (flaming, smouldering, and residual smouldering). The FCCS user is advised to apply a consumption factor based on fuel moisture — available in Consume (Ottmar et al. 1993, 2005) — to achieve an accurate estimate of consumption under specific environmental conditions.

AFP component 1

Flame available fuel (FA) is the sum of mass (tonnes·ha^{-1}/10) within one-half inch (1 in. = 25.4 mm) of the surface of the fuel element, and in turn is the sum of three subcomponents:[3]

1. Flame-reactive surface available fuel (FAR) is the mass of fuel consumed in the flaming front of a spreading surface fire that contributes to forward energy transfer, also known as the reaction zone (Frandsen 1971). It is the mass of thermally thin fuel elements plus a thin shell of larger fuel elements, with a thickness that represents the depth of the pyrolysis zone (defined as reaction thickness, ς_R). The surface fuel includes the shrub (foliage only), nonwoody, woody, and litter–lichen–moss strata.
2. Flame-available postreactive surface fuel (FAP) is the remainder of flame-available surface fuel after the passage of the flaming front, plus the flame-available fuel in the ground stratum (duff, humus, and fibric layers), if present.
3. Flame-available canopy fuel (FAC) is the mass of foliage and fine (<0.6 cm) twigs in the flammable tree canopy.

AFP component 2

Smouldering available fuel (SA) is the mass between 1.3 and 5.1 cm of a surface, representing fuels preconditioned (dehydrated) by the flaming stage and consumed in glowing combustion.

AFP component 3

Residual available fuel (RA) is the mass between 5.1 and 10.12 cm of a particle surface and the mass of the ground fuel stratum between 10.2 and 30.5 cm of the ground surface, representing the fuel available for residual smouldering. This combustion stage may last for many hours or days.

The user is provided with FA, SA, and RA, scaled to a maximum value of 10, and may use any meaningful combination of these component potentials to meet their objectives. By default, the FCCS calculator will consider AFP to be the sum of the three component potentials.

Applications of FCCS fire potentials

FCCS fire potentials are a set of relative values that rate the intrinsic physical capacity of a wildland fuelbed to release energy and to spread, crown, consume, and smolder. Development of the potentials required derivation of new algorithms to express surface fire spread and intensity in realistically heterogeneous, inventoried fuelbeds (Sandberg et al. 2007) and to provide a broader framework for rating the likelihood of crown fire (Schaaf et al. 2007). Measures of potential fire behaviour and effects are necessary to describe, classify, and map fuelbeds in terms of the expected outcomes of fire in those fuelbeds. Managers of prescribed fire and wildfires are typically interested first in surface fire spread rates and intensity, the probability of extreme fire behaviours such as crowning, and the immediate fire effects such as fuel consumption. Those outcomes, consistent with decision support systems most often used by managers in the United States, are the focus of FCCS fire potentials in this paper. The authors intend that fire managers find them useful in objectively and consistently comparing the expected outcomes of fire among fuelbeds that differ by location, time, or as the result of fuels management or disturbance events.

For example, fire managers are keenly interested in the difference in expected fire behaviour and effects attributable to fuels management. Consider a heavily stocked mixed-conifer stand in the western United States such as typified by FCCS fuelbed 208: grand fir – Douglas-fir forest with fire exclusion Riccardi et al. (2007). FCCS fire potential for this untreated fuelbed is 379 representing a below average potential surface fire behaviour,[4] above average crowning potential, and extremely heavy available fuel. If thinned from below in a simulation using FCCS version 1.1 (Ottmar

[3] These three subcomponents of flame available fuel are calculated but are not visible in reports available in FCCS version 1.0.

[4] If this untreated fuelbed burned under moderate fuel moisture conditions, the reformulated surface fire model by Sandberg et al. (2007) would predict a reaction intensity of 466 kW·m^{-2}, a rate of spread of 3.9 m·min^{-1}, and a flame length of 2.1 m.

et al. 2007), the FCCS fire potential would change to 829, representing lower crowning potential owing to the removal of crowns, but an increase in surface fire potential[5] because of fuel being left on the ground. Taken one step further, it is possible to simulate a prescribed underburn in this fuelbed to remove the downed woody fuel, thereby reducing the FCCS fire potential to 134 because of the fuels consumed in the treatment. Alternative treatments could be simulated to seek the best outcome.

Many other applications of FCCS fire potentials are possible. For example, users could be interested in how the fire potential and available biomass would change under a scenario of global warming that has been translated into structural changes in a fuelbed (such as woody invasion, changing ecosystem species composition, changing decomposition rates, tree mortality, etc.). No matter how simple or complex a change was envisioned or monitored in the fuelbed, FCCS version 1.1 would compute the relative change in FCCS fire potentials automatically, objectively, and quantitatively. In some cases, where fuel moistures and wind speed are known to the user, absolute values of fire behaviour and effects are also obtainable.

Fuelbeds represent potential energy that can result in a wide range of fire behaviours and fire effects, depending on physical fuel characteristics and on environmental conditions under which they burn. The FCCS focuses on cataloguing and summarizing the intrinsic characteristics of fuelbeds in a universal system designed to provide input to fire behaviour and effects models. The FCCS facilitates analysis of changes in fuelbeds as a result of the passage of time, fuel management, and natural disturbance, and quantifies the difference in fire potential between fuelbeds to prioritize management activity. The FCCS provides a robust methodology for estimating fire behaviour and effects for all types of fuelbeds at benchmark weather and fuel moisture conditions.

Other users such as those in Canada, Mexico, and Australia, and other values such as carbon accounting, environmental effect, and ecological response, could be addressed in the future by following the example set by the original FCCS fire potentials. Several additional FCCS fire potentials are under development to meet future needs of users, depending on which measure of fire behaviour or effect is considered important, which assumptions are made or models are used to calculate that measure, and which benchmark environmental conditions are appropriate for the calculations. For example, potentials will be developed to facilitate calculation of air pollutant and carbon emissions, flaming and smouldering residence time, carbon stores and fluxes, and fire behaviour predictions consistent with other fire behaviour models.

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