1.8 # FUEL CHARACTERISTIC CLASSIFICATION SYSTEM

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1. ABSTRACT

The ongoing development of more sophisticated fire models and the implementation of large landscape assessments has demonstrated the need for a comprehensive system of fuelbed classification that more acurately captures the structural complexity and geographical diversity of fuelbeds. The Fire and Environmental Research Applications team (FERA) of the Pacific Northwest Research Station, U.S Department of Agriculture, Forest Service, is developing a National System of Fuel Characteristic Classification (FCCS) to accommodate this need. The system will offer consistently organized fuels data along with numerical inputs to fire behavior, fire effects, and dynamic vegetation models. Users can generate fuel characteristics by accessing existing fuelbed descriptions (fuelbed prototypes) using generic information such as ecoregion, vegetation form, and cover type. Fuelbed default settings can be enhanced using more detailed information on vegetation structure and fuel biomass. When the user has completed editing fuelbed data, the FCCS calculates quantitative fuel characteristics (physical, chemical, and structural properties) and probable fire parameters. The system will assign the selected or enhanced fuelbed a fire behavior fuel model and a FCCS fuelbed fire potential index that describes the fuel complex based on potential fire behavior, crown fire, and available fuel. These fuelbed fire potentials will faciltate communication among users and provide a relative capacity of a fuelbed for surface fire behavior, crown fire and fuel consumption.

The FCCS is supported by a large data library that warehouses fuels information including biomass equations, physiognomic features, and physical parameters. This information was compiled from published and unpublished literature, photo series datasets, and expert opinion from across the United States. The system will be available for downloading from a website in late 2003.

2. INTRODUCTION

The development of spatial fuel property layers has always been important to fire and fuel managers and is becoming increasingly important to ecologists, air quality managers, and carbon balance modelers. As the source of all fire behavior and fire effects, fuelbeds must be characterized and mapped before any calculation of fire potential and hazard can be made. Fuel mapping, hazard assessment, evaluation of fuel treatment options and sequences, and monitoring fire effects all require a consistent and scientifically applied fuel classification system.

It would be prohibitively difficult to inventory all fuelbed characteristics every time a fire event prediction or fire management decision was necessary. Fuelbeds are structurally complex, vary widely in their physical attributes, potential fire behavior and effects, and in options they present for fire control and use. An organized method of classifying fuels and inferring fuelbed properties from both limited and detailed observations is needed to satisfy a variety of potential users. We also need a system that serves a variety of users and reasonably organizes some of the complexity of wildland fuelbeds without oversimplyfing their description.

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The fuel classification for most of the twentieth century has focused primarily on the rate of spread, resistance to control, and the flame length of initiating fires in surface fuels (Sandberg and others 2001). This focus has ably served the need for fire suppression planning and has become increasingly quantitative as tools for numerical assessment of hazard have become available. Thirteen stylized fire behavior fuel models have simply and adequately filled this need (Albini 1976). However, this focus has not satisfied the need to predict extreme fire behavior or model fire behavior and effects related to the residence time, persistence, or the total heat release (biomass consumption) from fires burning throughout all fuel layers. The existing fuel models do not accurately characterize the actual fuel character and variability found in nature. There is an effort underway (Scott and others in preparation) that will add to these 13 fire behavior fuel models. The original 13 along with the additional 30 models will continue to be useful to fire managers using the current generation of fire behavior models.

Between 1995 and 1999, the Fire Emissions Tradeoff Model (FETM) (Schaaf 1996) was developed to demonstrate the tradeoffs between wildfire and prescribed fire emissions and the Interior Columbia River Basin Assessment (Ottmar and others 1998) and Grand Canyon Visibility Transport Commission Assessment were underway (Air Sciences Inc. 2003). All efforts required a more robust way to assign fuel loadings across landscapes than the 13 fire behavior models could provide. Fuel condition classes (Schaaf 1996, Ottmar and others 1998) were developed to improve fuel loading assignments. The fuel condition class system was the forerunner of the fuel characteristic classification system.

This paper presents the design of a system that characterizes and classifies fuelbeds. The objective in designing the fuel characteristic classification system (FCCS) is to provide fuel managers with a nationally consistent and durable system to classify fuelbeds and to provide numerical inputs to fire behavior, fire effects, and dynamic vegetation models.

3. FUELBED CLASSIFICATION

The Fire and Environmental Research Applications Team (FERA) of the USDA Forest Service, Pacific Northwest Research Station, is currently developing the FCCS for national application with funding from the Joint Fire Science Program and National Fire Plan. The major criteria for system design included:

1. Applicability throughout the United States.
2. Accommodation of a wide range of potential users, operating at different scales, with various levels of detail, quality and quantity of data.
3. Scientifically sound.
4. Comprehensive.
5. Flexible and expandable.
6. Standardized and repeatable.
7. Easily understood and learned.

The general design of the FCCS (figure 1) allows users to access existing fuelbed descriptions (fuelbed prototypes) or modify existing descriptions to create enhanced fuelbeds. The system generates a list of fuelbed prototypes that most closely aligns with several general user inputs including the Bailey's ecoregion and vegetative form. The user then selects the most appropriate fuelbed prototype from the list. The selected prototype provides the best available predictions of the types of fuel (fuelbed strata and categories) and their quality (physiognomy) and relative abundance (gradient variables). The user can accept these default settings or modify some or all of them using site-specific knowledge. When the user has completed editing the qualitative and quantitative fuelbed data, the FCCS calculates quantitative fuel characteristics (physical, chemical, and structural properties) and probable fire parameters specific to the fuelbed in question. Each user-described fuelbed is also assigned to one of 192 fuel characteristic class potentials and will be assigned one of the 13 fire behavior fuel model (Albini 1976) and one of the 20 National Fire Danger Rating System models (Deeming and others 1977).

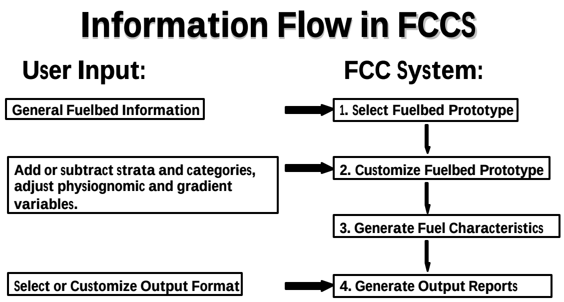

Fig. 1. User-provided general fuelbed information identifies a fuelbed prototype(s). The prototype identifies the types of fuel present (fuelbed strata and categories) and their qualitative (physiognomy) and quantitative (gradient variables) features. The user can then enhance the prototypic information. The system will calculate fuel properties and fire parameters based on the enhanced fuelbed data, and will assign the fuelbed to a fuel characteristic class potential and a fuel model.

4. A GENERIC FUELBED

The FCCS stratifies fuelbeds into 6 horizontal fuelbed stata that represent unique combustion environments (fig. 2). The use of fuelbed strata facilitates the creation of spatial data layers and allows the user to include, combine, or exclude as much detail as is needed to suit a particular use.

Each fuelbed stratum is broken into one or more fuel types, with common combustion characteristics, called fuelbed categories (fig. 2). There are sixteen fuelbed categories in total.
The ground fuel stratum, for example, includes duff as a fuelbed category. Duff is the partially decomposed organic material above the mineral soil that lies beneath the freshly fallen twigs, needles and leaves and is often referred to as the F (fermentation) and H (humus) layers.

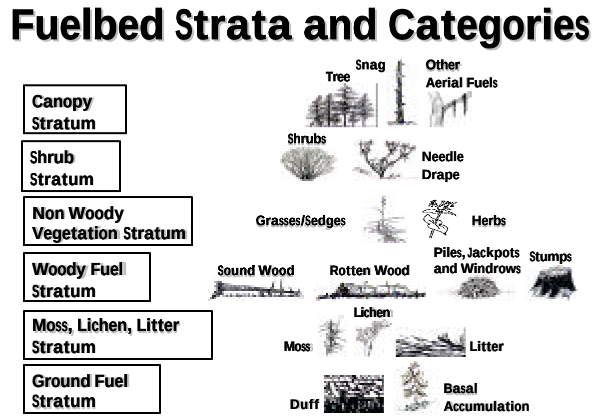

Fig. 2. Fuelbed strata and categories

Each fuelbed category is described by physiognomic and gradient variables. Physiognomic variables capture qualitative features of the category, including morphological, chemical and physical features. The duff category of the ground stratum for example, includes physiognomic variables of the fermentation and humus layer and the derivation of that material (i.e. decayed moss, needle litter, leaf litter).

Gradient variables characterize the relative abundance of fuel. The duff category includes the gradient variables of mean duff thickness and proportion of rotten material. With these estimates of fuel character (physiognomic variables) and abundance (gradient variables) the system calculates total upper duff and lower duff bulk density and fuel loading of the duff category and other parameters required as inputs by fire models.

5. FUELBED PROTOTYPES

The FCCS provides a set of prepared fuelbed descriptions or prototypes that are given a fuelbed name and fuelbed numeric identification. The system has approximately 250 fuelbed prototypes at this time, but we have developed a process to increase that number by 10 fold within two years. These fuelbed prototypes are designed to include most major fuelbed types throughout the United States and represent a general classification of vegetation type (vegetation form and cover type) and of fire potential (fire effects and fire behavior).

Users can access fuelbed prototypes with only limited or partial general fuelbed information. The FCCS will allow authorized users to add new fuelbed prototypes to the system database so that the system will include a greater variety of fuelbed descriptions. The general fuelbed information used to organize the fuelbed prototypes will include:

- Ecoregion Division (Bailey 1997): Fuelbed prototypes are organized geographically to improve prototype selection when only very general information such as vegetation form is available.
- Vegetation Form: Vegetation form describes the gross physiognomic structure of a landscape unit. Options include conifer forest, hardwood forest, mixed forest, shrubland, grassland and savanna. Coupled with a choice of ecoregion division, the system provides the user with a pull-down menu of all the conifer forest prototypes available for a certain division. Vegetation form can also be used with remote sensing data where only very general information about vegetation is available.
- Cover Type: The FCCS uses a synthetic classification of cover type based on dominant vegetation and fire potential but crosswalks, whenever possible, to existing cover type classifications (for example, Eyre 1980, Shiflet 1994).
- Structural Class: Structural class applies mainly to forests and captures the number of canopy layers, the relative size of trees, the stage of understory and the relative degree of stand closure. Descriptions of forest structure are used to fine tune the categories present and the partitioning of fuels in canopy layers.
- Change Agent: Change agent refers to activities such as fire suppression, insect and disease mortality, wind and timber harvesting that significantly alter fuelbeds. Fuelbed prototypes reflect a range of possibilities.

6. FUEL CHARACTERISTICS AND FUELBED FIRE POTENTIAL OUTPUTS

The FCCS has the ability to provide users with continuous fuel characteristics, based on user input and a potential fuel characteristic class. Several different output formats will be available but a complete output file includes:

- Fuelbed name and description as provided by the user;
- All input information provided by the user or inferred by the FCCS;
- All fuel characteristics generated by the system including fuel loading and fuel surface area;
- Fuel Characteristic Class potential;
- National Fire Danger Rating System (NFDRS) and Fire Behavior fuel model assignments; and
- Reliability or data quality index

Fuel characteristics are calculated or inferred using the best available published and, where necessary, unpublished data. This information includes biomass equations, photo series and other published fuels data, and relationships between physiognomic features and physical parameters such as surface-area-to-volume ratio, bulk density, and flammability. This information is stored in an internal FCCS file with a rule base that links information to the appropriate fuelbed.

Generating continuous fuel characteristics specifically for the fuelbed in question creates some potential problems:

1. It limits the ability of users to communicate and compare fuelbeds.
2. Many fire models require stylized input data that must be calibrated to generate appropriate model behavior.

To address these issues and to provide a relative intrinsic capacity of a fuelbed's fire behavior, crowning potential, and fuel consumption, the FCCS includes a set of fuelbed fire potentials based on three key attributes (fig. 3):

1. Index of fire behavior potential
2. Index of crown fire potential
3. Index of available fuel potential

The FCCS number assigned to each fuelbed indicates the level of each index. The FCCS #923 will have a fire behavior potential index of 9, a crowning potential index of 2, and an available fuel potential index of 3.

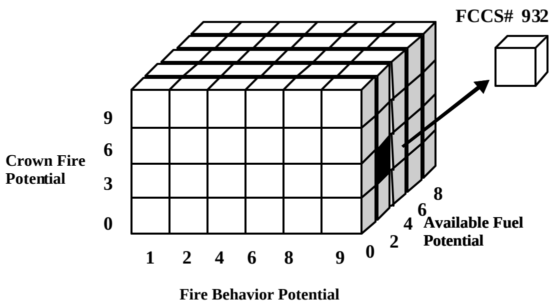

Fig. 3. 192 fuel characteristic class system potentials in 3-dimensional space grouped by three critical attributes of fire behavior, crowning and available fuel potentials.

7. IMPLEMENTATION

A series of six workshops with fuels experts and potential users of the system were held around the United States to ensure regional applicability of the system. The system design, 250 fuelbed prototypes, and internal equations within the FCCS calculator to generate fuelbed characteristics and assign fuelbed fire potentials are complete. The user interface and data engineering is in the final development phase and will guide the user through the system (fig. 4). The system is very flexible and will allow users to:

- Select a fuelbed prototype based on general fuelbed information and accept default fuel characteristics.
- Select a fuelbed prototype and modify or enhance the default settings based on site-specific knowledge.
- Create enhanced fuelbeds (and custom fuelbed databases).
- Transform output data matrix to fit other fire and vegetation models.
- Batch a series of selected or enhanced fuelbed and associated characteristics into other software.

Efforts are also underway to ensure that the FCCS will link with existing fire and landscape assessment models. Linkages with FFE-FVS (Fire and Fuels Extension to the Forest Vegetation Simulator), CONSUME (model that predicts fuel consumption and emissions), Fire Effects Tradeoff Model (a model to evaluate the tradeoffs between wildfires and prescribed fires), and FASTRAC (a database model designed to compile fuels information) are currently in progress. Additional linkages to other fire models such as Behave, Farsite, and the First Order Fire Effects Model (FOFEM) are anticipated.

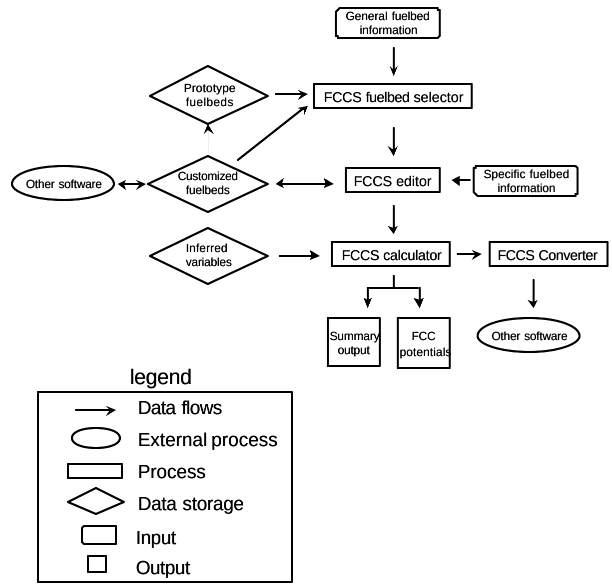

Fig. 4. Fuel Characteristic Classification System data flow diagram.

A prototype of the FCCS was developed and tested in 2002 and the system will be fully operational by late 2003. The FCCS is designed to learn. Data quality will be indexed and protocols will be in place to append new information and replace inaccurate information.

8. SUMMARY

The objective of the FCCS is to provide fuels data to a large number of people in many different disciplines over a broad geographic area. We hope this system will eventually have international applicability. The FCCS will be adaptive and respond to the needs and input of users. The system will be continually updated and improved as more information is added to the data base, new equations are added to the calculator, and feedback from the users is accommodated.

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