The fuelbed: a key element of the Fuel Characteristic Classification System[1]

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Abstract: Wildland fuelbed characteristics are temporally and spatially complex and can vary widely across regions. To capture this variability, we designed the Fuel Characteristic Classification System (FCCS), a national system to create fuelbeds and classify those fuelbeds for their capacity to support fire and consume fuels. This paper describes the structure of the fuelbeds internal to FCCS. Fuelbeds are considered relatively homogeneous units on the landscape, representing distinct combustion environments that determine potential fire behaviour and effects. The FCCS fuelbeds are organized into six strata: canopy, shrubs, nonwoody fuels, woody fuels, litter–lichen–moss, and ground fuels. Fuelbeds are described by several qualitative and quantitative physical and biological variables with emphasis on characteristics useful for fuels management and fire behaviour planning. The FCCS includes 216 fuelbeds that represent the major vegetation types of the United States. The FCCS fuelbeds can be used as presented or modified to create customized fuelbeds with general or site-specific data to address fire science management or research questions. This system allows resource managers to evaluate wildland fuels operations and management activities, fire hazard, and ecological and air quality impacts at small and large spatial scales. The FCCS fuelbeds represent the United States, although the system has the potential for building fuelbeds for international application.

Résumé : Les caractéristiques des couches de combustibles en milieu naturel sont complexes dans le temps et l'espace et peuvent varier énormément d'une région à l'autre. Dans le but de saisir cette variabilité, nous avons élaboré le système de classification des caractéristiques des combustibles (SCCC), un système national pour créer et classer ces couches de combustibles selon leur capacité à supporter un feu et à consumer des combustibles. Cet article décrit la structure des couches de combustibles intrinsèques au SCCC. Les couches de combustibles sont considérées comme des unités relativement homogènes dans le paysage et représentent des milieux de combustion distincts qui déterminent les effets et le comportement potentiel du feu. Les couches de combustibles du SCCC sont organisées en six strates : canopée, arbustes, combustibles non ligneux, combustibles ligneux, litière-lichens-mousses et combustibles au sol. Les couches de combustibles sont caractérisées par plusieurs variables physiques et biologiques qualitatives et quantitatives en mettant l'accent sur les caractéristiques utiles pour la gestion des combustibles et la planification du comportement du feu. Le SCCC inclut 216 couches de combustibles qui représentent les principaux types de végétation des États-Unis. Les couches de combustibles du SCCC peuvent être utilisées telles quelles ou modifiées pour créer des couches de combustibles sur mesure à partir de données générales ou spécifiques à une station pour s'attaquer à des problèmes de recherche ou de gestion en pyrologie forestière. Ce système permet aux gestionnaires d'évaluer les activités de gestion et les interventions visant les combustibles en milieu naturel, le risque d'incendie ainsi que les impacts écologiques et sur la qualité de l'air à petite ou grande échelle. Les couches de combustibles du SCCC sont représentatives des États-Unis mais le système offre la possibilité d'élaborer des couches de combustibles pour une application internationale.

[Traduit par la Rédaction]

Introduction

Fuels are often defined as the physical characteristics (e.g., loading, depth, height, and bulk density) of live and dead biomass that contribute to wildland fire (Davis 1959). Because these characteristics affect the character, size, intensity, and duration of a fire, identifying and quantifying fuels are important in understanding fire behaviour and ef-

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fects, as well as in providing information for activities such as prescribed fire, fire suppression, and fuel treatments. Furthermore, fuelbed characteristics are important aspects to consider when assessing wildlife habitat and carbon stores.

Fuel characteristics often vary widely across regions (Ottmar et al. 2007). For instance, fuel loads can range from (1) <0.6 t·ha^{-1} for a perennial grassland in the central part of the United States with no rotten woody material or duff (organic material that includes Oe horizon and Oa horizon), to (2) 35 t·ha^{-1} in a woodland in California with a grass and shrub understory and a litter layer, to (3) 195 t·ha^{-1} in a mixed conifer forest with insect and disease mortality in the US Rocky Mountains with dead and down sound and rotten woody material, snags, litter and duff, and to (4) 381 t·ha^{-1} in a black spruce (*Picea mariana* (Mill.) BSP) forest of Alaska with a deep moss and organic forest floor layer (Ottmar and Vihnanek 1998, 1999; Ottmar et al. 1998*a*, 2007; Hardy et al. 2001).

It would be prohibitively difficult to inventory all fuelbed characteristics every time a fire behaviour or effects assessment is required (Sandberg et al. 2001; Ottmar et al. 2004). Attempts have been made during the past 30 years to develop systems to construct and classify fuelbeds for loading and other characteristics with various degrees of success. These include the original and standard fire behavior fuel models (Anderson 1982; Andrews and Chase 1989; Scott and Burgan 2005), National Fire Danger Rating System fuel models (Deeming et al. 1977), Fuel Condition Class System fuelbeds (Schaaf 1996; Ottmar et al. 1998*b*), First Order Fire Effects Model fuelbeds (Reinhardt et al. 1997; Reinhardt and Crookston 2003); Canadian Forest Fire Danger Rating System (Hirsch 1996); Australian Fire Danger Rating System fuel models (Cheney and Sullivan 1997; Cheney et al. 1990); Photo Series (Ottmar et al. 2004); and Fuel Load Models (Keane 2005; Rollins and Frame 2006). Many of these models were designed for specific software applications or as inputs to predict specific fire behaviour and effects. Therefore, they include the fuelbed components or characteristics required by the program or model they were designed to support. Consequently, these models do not capture all fuel components required to estimate fire behaviour and fire effects (Sandberg et al. 2001; Ottmar et al. 2007).

In this paper, we describe the structure of the FCCS fuelbeds that captures the complexity and diversity of wildland fuelbeds in the United States. The fuelbed design and classification discussed here is the basis for calculation of a common set of fuel characteristics (Riccardi et al. 2007) that are used as inputs into FCCS fire potentials and fire behaviour calculations (Sandberg et al. 2007*a*, 2007*b*; Schaaf et al. 2007) and that have a variety of applications in fire and fuels management and in ecological analysis.

FCCS fuelbeds

Definition of a fuelbed

An FCCS fuelbed is defined as the measured or averaged physical characteristics of a relatively uniform unit on the landscape that represents a distinct fire environment. (Sandberg et al. 2001, 2007*b*). The fuelbed can represent any scale or precision of interest and can be used to manage, predict, assess, or differentiate fire behaviour and effects.

Design of FCCS fuelbeds

The FCCS fuelbeds were initially designed by scientists, researchers, land managers, and other experts who participated in a series of FCCS fuelbed workshops for the boreal (Fairbanks, Alaska), tropical (Palm Coast, Florida), subtropical, dry (Phoenix, Arizona), western temperate (Welches, Oregon), subtropical (Atlanta, Georgia), and eastern temperate (Nebraska City, Nebraska) regions of the United States. The design of the fuelbed was required to account for all categories of biomass that had the potential to consume and affect fire behaviour and effects. To do this, an FCCS fuelbed is classified into six horizontal fuelbed strata that represent unique combustion environments: canopy, shrubs, nonwoody fuels, woody fuels, litter–lichen–moss, and ground fuels (Table 1 and Fig. 1). Strata are further divided into 18 fuelbed categories and 20 fuelbed subcategories. Any one or combination of these levels may or may not be present in a fuelbed (i.e., the canopy stratum may not be present in a grassland fuelbed). Similarly, variables differ among strata and categories because of differences in vegetation form. Reported values include the mode, minimum, and maximum values. The mode is the most frequently occurring value, while the minimum and maximum are the recommended limits based on the data from which the fuelbed is built. Statistical resolution of the data was necessary because it was decided that minimum, maximum, and modal fuels data were more accessible by estimation than arithmetic mean and standard errors. Each fuelbed is given a ranking (1–5) based on how much of the data came from experience (expert opinion), published literature, or other databases: 1, based on expert opinion only; 2, based on expert opinion with <35% modal data used; 3, based on expert opinion with 35%–85% modal data; 4, based on >85% modal data, with expert opinion; and 5, indicates >85% of the data for modal, minimum, and maximum values are based on literature, photo series, or other data sources. This ranking is displayed when an FCCS fuelbed is selected and viewed.

Several variables or analogous equivalents are present among strata. Percent cover, defined as surface area by crown projection of area covered, is used to express the relative importance of a fuelbed category within a fuelbed. Height (m) is the distance from the base to the top of a fuelbed category, whereas depth (cm) is the distance from the top downward. Live foliar moisture (%) is the water content of a live fuel expressed as a percentage of its ovendry weight. Default values represent low-end moisture conditions. Density (stems·ha^{-1}) is the number per unit area. Diameter (cm) and diameter at breast height (DBH; cm) represent a modal value for the stratum, category, or subcategory rather than individual elements (i.e., tree). Where appropriate, species designations are required and must be associated with a relative cover (%), the relative amount of a fixed area covered by a species or fuelbed category. Variables specific to strata, categories, or subcategories are discussed within the context of their respective arrangement. To facilitate discussion we begin with the canopy and finish with ground fuels.

Table 1. Fuel Characteristic Classification System (FCCS) fuelbed variables and affected fire potentials.

Stratum	Category	Subcategory	Variables	Affected fire potentials
Canopy	Trees	Total canopy cover	Percent cover (%)	C
		Overstory, midstory, and understory	Percent cover (%)	C, A
			Height (m)	C, A
			Height to live crown (m)	C, A
			Live foliar moisture content (%)	C
			Density (no.· ha^{-1})	
			Diameter at breast height (DBH; cm)	
			Species and relative cover (%)	C, A
	Snags	Class 1 (foliage present), class 1 (foliage absent), class 2 (branches and bark present), and class 3 (rotten; no branches and bark)	Stem density (number ha^{-1})	C, A
			Diameter (cm)	A
			Height (m)	C, A
			Species and relative cover (%)	C, A
	Ladder fuels		Type	C, A
			Minimum height (m)	C
			Maximum height (m)	C
			Vertical continuity between the canopy and lower strata (yes/no)	C
Shrub	Primary layer and secondary layer		Percent cover (%)	S, A
			Height (m)	A
			Percent live (%)	S
			Live foliar moisture content (%)	S
			Species and relative cover (%)	S, A
			Needle drape on shrubs sufficient to affect fire behaviour (yes/no)	S
Nonwoody fuels	Primary layer and secondary layer		Percent cover (%)	S, A
			Height (m)	A
			Percentage live (%)	S
			Live foliar moisture content (%)	S
			Loading (Mg ha^{-1})	S, A
			Species and relative cover (%)	S, A
Woody fuels	All woody		Total percent cover of all downed and dead woody fuel (%)	S, A
			Depth (m)	S
	Sound wood	Loadings 0–7.5 cm diameter	Loading by size-class (Mg ha^{-1})[a]	S, A
		Loadings >7.5 cm diameter	Loading by size-class (Mg ·ha^{-1})[a]	S, A
			Species and relative cover (%)	S, A
	Rotten wood	Loadings >7.5 cm	Loading by size-class (Mg·ha^{-1})	S, A
			Species and relative cover (%)	S, A
	Stumps	Sound	Density (no.·ha^{-1})	A
		Rotten	Diameter (cm)	A
		Lightered–pitchy	Height (m)	A
			Species and relative cover (%)	A
	Woody fuel accumulations	Piles	Width (m)	A
		Jackpots	Length (m)	A
		Windrows	Height (m)	A
			Density (no.·ha^{-1})	A
Litter–lichen–moss	Litter		Arrangement (fluffy, perched, or freshly fallen)	S, A
			Type[b]	S, A
			For overall litter	
			Depth (cm)	S, A
			Percent cover (%)	S, A
			For each litter type	
			Relative cover (%)	S, A
	Lichen		Depth (cm)	S, A
			Percent cover (%)	S, A
	Moss		Type (spaghnum or other moss)	S, A
			Depth (cm)	A
			Percent cover (%)	S, A
	Duff	Percent rotten wood	Percent rotten (%)	
Ground fuels		Upper duff layer	Type[c]	A
		Lower duff layer	Depth (cm)	A
			Percent cover (%)	A

Table 1 (*concluded*).

Stratum	Category	Subcategory	Variables	Affected fire potentials
			Percent rotten wood total duff (%)	S, A
	Squirrel middens		Depth (cm)	A
			Radius (m)	A
			Density (no.·ha^{-1})	A
	Basal accumulations		Type[d]	A
			Depth (cm)	A
			Radius (m)	A
			Percent affected (%)	

Note: S, surface fire behaviour potential; C, crown fire behaviour potential; and A, available fuel potential.
[a]Sound wood size-classes: 0–0.6 cm, 0.7–2.5 cm, 2.6–7.5–cm, 7.6–22.9 cm, 23.0–50.8 cm, and >50.8 cm. Rotten wood size-classes: 7.6–22.9 cm, 23.0–50.8 cm, and >50.8 cm.
[b]Short needle pine, long needle pine, other conifer, deciduous hardwood, evergreen hardwood, palm frond, and grass.
[c]Upper duff types: dead litter and moss. Lower duff types: humus or muck and humic peat.
[d]Bark slough, branches, broadleaf deciduous, broadleaf evergreen, grass, needle litter, and palm fronds.

Canopy

The canopy stratum is the somewhat continuous coverage of branches and foliage formed collectively by crowns of adjacent trees and includes three categories: (1) trees, (2) snags, and (3) ladder fuels (Table 1 and Figs. 1 and 2). The tree category includes total canopy cover, overstory, midstory, and understory trees (Oliver and Larson 1996). Total canopy cover is the crown projection percent cover of all trees. The overstory includes the emergent, dominant and codominant trees. The understory includes seedlings, saplings, and other small trees. The midstory, if present, includes those trees below the overstory and above the understory. All trees are considered live and are generally taller than 1.37 m (exceptions are seedlings in the understory). Percent cover, height, and DBH represent values for the over-, mid-, and under-stories rather than individual trees. Height to live crown (m) is from the ground to the bottom of the live canopy. Live foliar moisture content mode, minimum, and maximum are 100%, 70%, and 300%, respectively. Density is the number of trees per unit area. Species and relative cover are included if the subcategory is present (Table 1).

Snags are standing dead trees taller than 1.37 m and include four subcategories: (1) class 1 with foliage, (2) class 1 without foliage, (3) class 2, and (4) class 3 (Maser et al. 1979). Class 1 snags have bark, branches, and tops intact, and are further distinguished by the presence or absence of foliage. Class 2 snags have shed fine branches, but retain coarse branches, and class 3 snags have extensive heartwood decay and no longer have bark or branches. Density, diameter, and height represent values for the subcategory. Species and relative cover are included if the subcategory is present (Table 1).

Ladder fuels provide vertical continuity between the surface and crown fuels. Minimum and maximum height from the ground is included for one of eight ladder fuel types (Table 1). Affirmation of pronounced vertical continuity between the surface and crown fuels provided by the ladder fuel is a choice within the system.

Shrubs and nonwoody fuels

Shrubs and nonwoody fuels may have two categories: (1) primary and (2) secondary. Shrubs are woody perennial plants that differ from trees owing to their low stature and multiple basal stems. The nonwoody fuels stratum includes herbaceous vegetation (i.e., forbs, grasses, rushes, and sedges). Percent cover and height represent values for this category. Percent live is the biomass that is alive in the category, not the percentage of individuals that are alive. Species and relative cover are included if the category is present (Table 1).

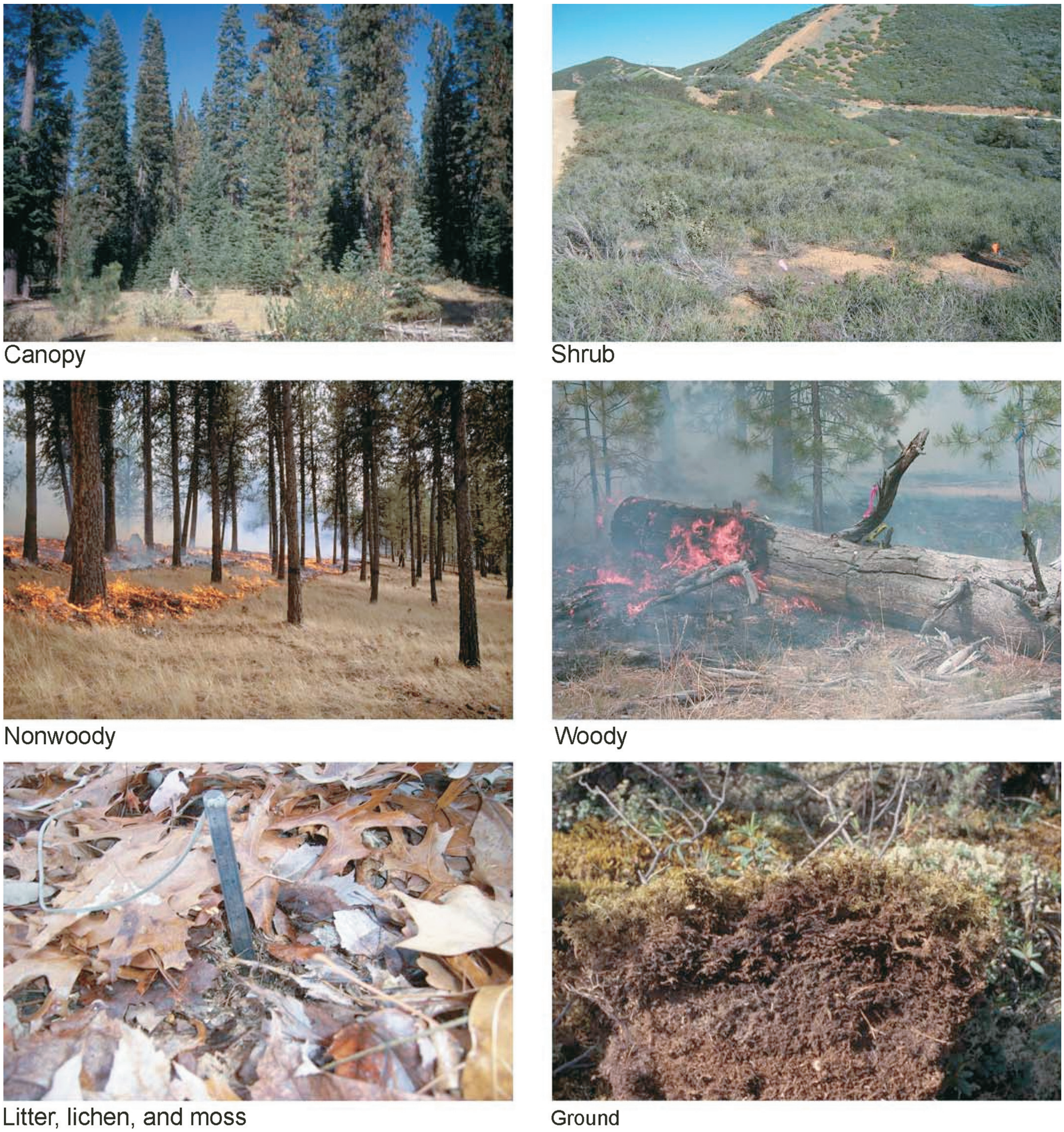
A few differences between the strata should be noted. The modes, minimums, and maximums of live foliar moisture content for shrubs and nonwoody fuels are 120%, 70%, and 300% and 75%, 70%, and 300%, respectively. Division of species into primary and secondary categories is optional. Distinction may occur because of pronounced differences in height, life form, species composition, or other defining attribute. Results from the tropical and subtropical regional workshops identified accumulated fallen needles on shrubs as an important fuel consideration. Therefore, needle drape is part of the shrub stratum and, if needle drape is sufficient to contribute to fire behaviour, it is indicated by a check mark in the shrub stratum. Loading is the mass per unit area (Mg·ha^{-1}), is in only the nonwoody stratum, and includes the biomass of the nonwoody fuels. Suggestions from all the workshops indicated few users would have shrub loading values, consequently, the value is calculated by using allometric equations and displayed in the reports (Riccardi et al. 2007).

Woody fuels

The woody fuels stratum includes continuous and discontinuous, downed and dead woody fuel. It is divided into five categories: (1) all downed and dead woody, (2) sound wood, (3) rotten wood, (4) stumps, and (5) woody fuel accumulations. Sound and rotten wood are considered continuous fuels whereas stumps and woody fuel accumulations are discontinuous fuels.

The all woody category describes the depth and percent cover of continuous downed and dead sound and rotten fuels (Table 1). Stumps and woody fuel accumulations are not included in this category. It is important to note that depth represents the value of continuous sound and rotten downed fuels across the entire fuelbed unit and not just at small-scale locations where the fuel is present. Percent cover is linear coverage because the measurement of intercept length (intercept distance) is used to estimate cover.

Fig. 1. The Fuel Characteristic Classification System (FCCS) is separated into six fuel categories including canopy, shrubs, nonwoody, woody, litter–lichen–moss, and ground fuels.

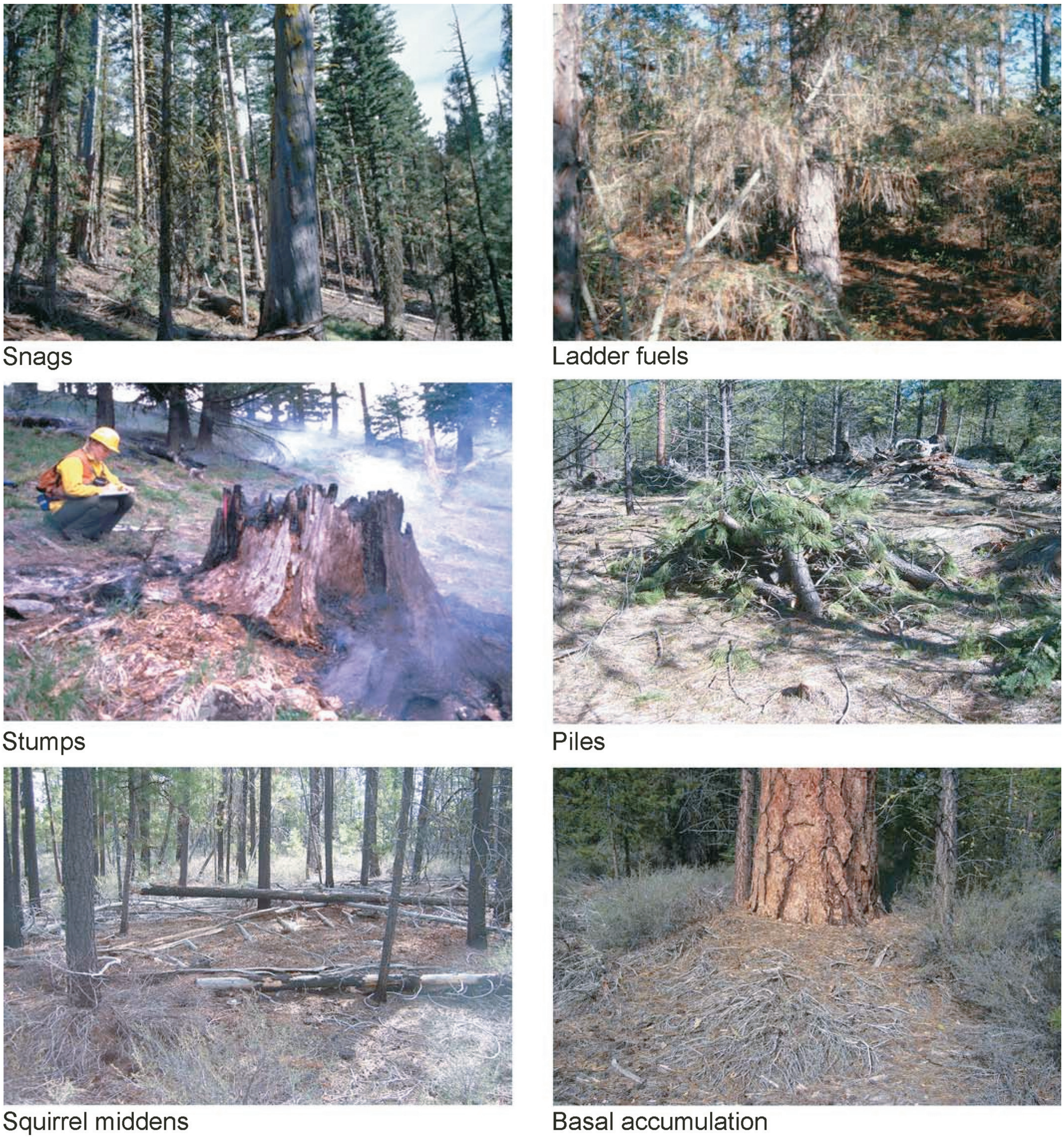


Sound and rotten fuels data are analogous data, and thus, are combined here, but are distinct categories and are treated as such in FCCS. Loading ($Mg \cdot ha^{-1}$) is reported by size-classes that correspond to timelag fuel classes most commonly used in fire behaviour modeling (Fosberg 1977). Species and relative cover are included for fuels >7.6 cm diameter (Table 1).

The stump category is divided into three subcategories: (1) sound, (2) rotten, and (3) lightered pitchy stumps. The latter are stumps with resin-soaked heartwood and were identified in the tropical and subtropical regional workshops as important fuel. Density is the number of stumps per unit area. Diameter and height are data for the subcategory, not for individuals. Species and relative cover are included if the subcategory is present (Table 1).

The woody fuel accumulation category contains three

Fig. 2. Example of several Fuel Characteristic Classification System (FCCS) fuelbed categories including snags, ladder fuels, stumps, piles, squirrel middens, and basal accumulation.



subcategories: (1) jackpots, (2) piles, and (3) windrows. Jackpots are natural accumulations of woody debris, whereas piles and windrows result from management activity. Variables are width (m), length (m), height (m), and density in each subcategory (Table 1).

Litter–lichen–moss

The litter–lichen–moss stratum has three categories. Litter is the top layer of the forest or rangeland floor and is composed of loose debris of dead sticks, branches, twigs, dead grass, and recently fallen leaves or needles, minimally altered by decomposition. It is analogous to the Oi soil horizon. Depth and percent cover of the category are augmented by the designation of a litter arrangement (Table 1). Analogous to the inclusion of species and relative cover in other strata, litter type and relative cover are in-

Table 2. Selection classification criteria for the Fuel Characteristic Classification System (FCCS) fuelbeds.

Criterion	Source	Required
Ecoregion	Bailey (1989)	Yes
Vegetation form	Grossman et al. (1998)	Yes
Structural class	Adapted from Oliver and Larson (1996)	No
Cover types	Eyre (1980) and Shiflet (1994)	No
Change agents		No
Natural fire regimes	www.frcc.gov	No
Fire regime condition class (FRCC)	www.frcc.gov	No

Table 3. Change agents of the Fuel Characteristic Classification System (FCCS) fuelbeds.

Category	Change agent
Change over time	Fire exclusion
	Introduction of exotic species
Fuel treatments	Chipping
	Lop and scatter
	Mastication
	Pile and burn
Land use change	Ditching–draining
	Paving
Natural event	Avalanche
	Windthrow
	Flood
	Ice storm
	Insects and disease
	Landslide
No change	None
Prescribed fire	Prescribed fire
Unknown	Unknown
Vegetation treatment or harvest–thinning	Clearcut
	Grazing
	Logging methods – equipment damage
	Pruning
	Salvage logging
	Selection cut (thin large diameter)
	Stump wooding
	Thinning (thin from below)
	Turpentining
	Residual fertilizer
	Restoration work
Wildfire	Wildfire
	Wildfire (crown)
	Wildfire (ground)

cluded, and any combination of the eight litter types (Table 1) is possible.

Lichen and moss categories include the ground lichen occurring on rocks, bare ground, or low vegetation, and the low-growing moss (bryophytes) usually occurring in moist habitats, respectively. Both categories include depth and percent cover data, with the only distinction being in the moss category containing a choice between two moss types (sphagnum moss or other moss) (Table 1).

Ground fuels

The last stratum includes duff, squirrel middens, and basal accumulations. Duff is the partially to fully decomposed organic material between litter and mineral soil and is analogous to the Oe and Oa soil horizons. Three subcategories of data describe the duff: (1) percent cover of rotten wood in all duff layers, and depth and percent cover of the (2) upper (fermentation) and (3) lower (humic) subcategories (Table 1).

The squirrel middens category was identified at the boreal and dry region workshops as important when considering fire behavior and effects in those regions. Squirrel middens are mounds of cone scales and other cone debris accumulated over time from squirrels exacting seeds. The mounds are composed of organic matter that can burn for extended periods of time. Data include radius (m), depth, and density (Table 1).

Basal accumulations include needles, twigs, bark pieces, litter, and duff that accumulate at the base of trees. Depth, radius (m), and the percent of trees affected (%) by accumulations are defined for one of seven types of accumulations (Table 1).

Development of FCCS fuelbeds

Experts at the six regional workshops created detailed quantitative and qualitative descriptions of fuelbeds in their regions. These data were verified and augmented with data taken from published, peer-reviewed literature, government databases (USDA Forest Service 2004), and other publications (e.g., US Forest Service research papers, general technical reports, research notes, stereo photo series for quantifying natural fuels, and photo series for quantifying forest residues), and unpublished data. A total of 216 FCCS fuelbeds[3] have been developed and placed into FCCS. They represent the major vegetation types of the United States. These fuelbeds have a general or site-specific focus, usually based on the data from which the fuelbed was built. General fuelbeds tend to represent a fuelbed type across its geographic and elevation range. These fuelbeds are designed to represent the broadest vegetation composition and structure of a unit. These data were taken from as wide a geographic range as possible. Site-specific fuelbeds tend to be based on a single site, unit, or geographic area. These data are often taken from only one source such as the photo series or a specific study.

Organization and naming convention of FCCS fuelbeds

Fuelbeds are organized by seven qualitative criteria: (1) ecoregion, (2) vegetation form, (3) structural class, (4) cover type, (5) change agent, (6) natural fire regime, and (7) fire

[3] Appendix A, Tables A1 and A2.

regime condition class (Table 2). These criteria enable a user to refine their search for a fuelbed. The criteria are adapted from published (often vegetation) classification systems (Eyre 1980; Bailey 1989; Shiflet 1994; Oliver and Larson 1996), with the exception of change agents. Change agents were determined from FCCS regional workshops and include disturbances that would affect a fuelbed such as natural disturbances (e.g., insects and disease and wildfire) silvicultural and management activities (e.g., thinning and prescribed fire), and human impacts (e.g., paving) (Table 3). As fuelbeds are created for fuels impacted by change agents, the fuelbeds become unavoidably more site specific because fewer data are available for replicate treatments or disturbances. Each fuelbed contains a site description that includes additional pertinent information, (e.g., major species described in the fuelbed, geographic distribution, elevation, details of the change agent, relative age of vegetation, and management or disturbance history, including time since disturbance or management activity).

The fuelbed file naming convention contains an assigned number, the name of the most prevalent species, and an associated change agent. Fuelbeds were assigned a number between 0 and 999 as they were built. In certain cases, fuelbeds were later deleted or combined resulting in a non-sequential list of fuelbed numbers.[4] The change agent is designated by a parenthesis in the file name.

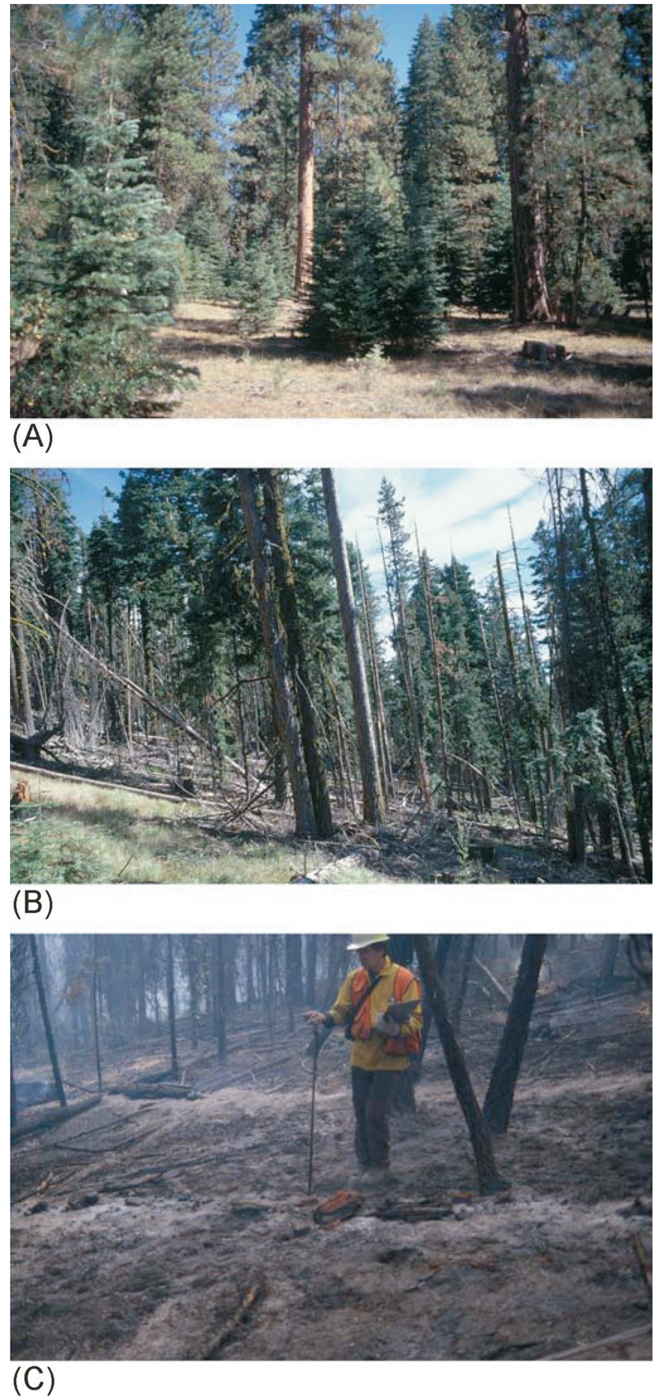


Fig. 3. The Fuel Characteristic Classification System (FCCS) fuelbed can be customized to represent (A) a unit that has not been treated, (B) a unit thinned from below with fuels untreated, and (C) a unit thinned from below with fuels treated with fire.

Customizing fuelbeds

Each FCCS fuelbed can be modified so that fuels data are customized for a particular management or research objective. Using FCCS, fuelbeds may be created from photo series, fuel inventories, or other fuels data sources. The protocol for naming fuelbeds is that species occurring in the same stratum are separated by a hyphen (–), and those occurring in different strata are separated by a slash (/).[5] Species occurring in the uppermost strata are listed first, followed successively by those in lower strata. The order of species name generally reflects decreasing levels of dominance, constancy, or indicator value. Herbaceous species are included if diagnostic. The vegetation form is at the end of the name.

Discussion

The FCCS provides a comprehensive approach to describing a fuelbed that is useful across the entire scope of fire science and management and has implications for use in many other disciplines such as wildlife and carbon accounting. The FCCS is organized around the fuelbed. The fuelbed is defined as measured or averaged physical characteristics of a relatively uniform unit on the landscape that represents a distinct fire environment and is designed to account for nearly all fuels that have a potential to consume. The FCCS offers a set of FCCS fuelbeds that are designed to be modified, if necessary, to create customized fuelbeds unique to a particular area of interest or research question. These fuelbeds have been mapped across the contiguous United States at a 1 km scale and are currently being used by the US Environmental Protection Agency to calculate and track emissions produced from wildland fire (McKenzie et al. 2007).

The FCCS provides several advantages with respect to advancing research in fuels science and management. Each variable discussed (Table 1) may be modified to (1) capture variability in fuels and (2) to create customized fuelbed(s)

[4] Appendix A, Table A1.
[5] Appendix A, Table A1.

Table 4. (*a*) Fuelbed inputs and calculated outputs and (*b*) Fuel Characteristic Classification System (FCCS) fire potentials (index values) for example fuelbeds.

(*a*) Fuelbed inputs and calculated outputs.

Strata	Category	Input variable	Fuelbed (natural)	Fuelbed (thinned from below)	Fuelbed (thinned from below and burned)
Canopy	Overstory	Percent cover (%)	20.0	15.0	15.0
		Height (m)	35.1	24.4	24.4
		Height to live crown (m)	10.7	3.0	3.0
		Density (trees·ha^{-1})	10.0	8.0	8.0
		Diameter at breast height (DBH; cm)	68.6	63.5	63.5
	Midstory	Percent cover (%)	40.0	5.0	5.0
		Height (m)	22.9	19.8	19.8
		Height to live crown (m)	9.1	3.0	3.0
		Density (trees·ha^{-1})	36.0	4.0	4.0
		Diameter at breast height (DBH; cm)	38.1	30.5	30.5
	Snags	Decay class 2 (trees·ha^{-1})	12.0	4.0	4.0
		Decay class 3 (trees·ha^{-1})	16.0	4.0	4.0
Woody		All woody depth (cm)	10.2	15.2	2.5
		Woody cover (%)	81.0	95.0	20.0
		0.0–0.6 (t·ha^{-1})	1.1	2.2	0.9
		0.6–2.5 (t·ha^{-1})	3.6	6.7	1.8
		2.5–7.6 (t·ha^{-1})	7.4	12.6	0.4
		7.6–22.9 (t·ha^{-1})	9.7	13.5	2.5
		22.9–51.0 (t·ha^{-1})	20.0	26.9	0.4
		>51.0 (t·ha^{-1})	7.6	9.0	1.1
Litter–lichen–moss		Litter (cm)	1.0	1.5	0.3
Ground		Upper duff (cm)	2.5	2.3	0.3
		Lower duff (cm)	2.5	2.3	0.3

(*b*) FCCS fire potentials (index values).

	Index values		
Potential type	Fuelbed (natural)	Fuelbed (thinned from below)	Fuelbed (thinned from below and burned)
FCCS fire potential	379	839	134
Surface fire behaviour potential	3	8	1
Crown fire behaviour potential	7	3	3
Available fuel potential	9	9	4

particular to a stand, unit, forest, state, region, or any other scale of choice. This design can be used to capture complexity and variability of fuels across time and space. For example, modification of height, percent cover, and density of trees (overstory, midstory, or understory) can be used to represent the effects of a thinning operation on fuels. Changes to the values of the percentage live and live foliar moisture in either the shrubs or nonwoody fuels can be used to represent a temporal change of season (i.e., growing versus dormant). Many possibilities exist because every variable is changeable. Extensive, detailed data within, and produced by, FCCS can be used for fuels operation and management activities, fire science, ecological analysis, and atmospheric science.

The FCCS fuelbeds are the basis for two components of FCCS, namely the calculation of physical characteristics and properties, (Riccardi et al. 2007) and FCCS fire potentials (Sandberg et al. 2007*a*; Schaaf et al. 2007). Calculation of physical characteristics (Riccardi et al. 2007) uses FCCS fuelbeds to provide inputs necessary to run current fuel consumption and emission production models. In addition, FCCS provides fuels data that can be used to enhance the state of fire modeling to include missing fuel categories such as flash fuels, large wood debris, and litter. The comprehensive, dynamic, and flexible design of FCCS fuelbeds provides an opportunity and data for comparisons with the use of mathematical models (Rothermel 1972, 1991; Van Wagner 1977) and the packaging of these models into computer simulations (Andrews 1986; Andrews and Chase 1989; Finney 1998; Beukema et al. 1999). Furthermore, many of the fuelbed characteristics can be used in other models or systems such as the First Order Fire Effects Model (Reinhardt et al. 1997) and BlueSky (Pouliot et al. 2005).

Exactly how can a user take advantage of FCCS and its fuelbeds? As one would expect, there are a limitless number of possible fuelbeds throughout the United States with distinctly different fuelbed strata, categories, and subcategories. These fuelbed categorical differences can be critical in determining potential surface and crown fire behaviour, fuel available for consumption, and tallying total carbon stores. Furthermore, the differences will dictate potential fire effects such as smoke production and tree mortality, and demonstrate the effectiveness of fuel treatment. Consider a 200 ha Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) and ponderosa pine (*Pinus ponderosa* Dougl. ex P. & C. Laws.) forest near several summer homes that is 200 years old and has been protected from fire for the past 100 years (Fig. 3). How can FCCS fuelbeds be used to outline an effective fuels treatment plan for the area? First, assume this stand will be thinned with no initial fuel treatment and later burned with a prescribed fire (Fig. 3). Table 4*a* displays a partial list of the fuelbed strata, categories, and subcategories created to represent each stand based on inventoried data. Table 4*b* provides an FCCS fire potential for surface fire behaviour, crown fire behaviour, and available fuel for each stage of treatment (Riccardi et al. 2007; Sandberg et al. 2007*a*).

The surface fire behaviour potential increases from 3 to 8 after thinning because the remaining fuels were not treated. Crown fire potential decreases from 7 to 3 because the removal of the midstory left a large gap between the overstory crown and the remaining midstory trees. This lowered the potential of the surface flames reaching the crowns. The available fuel increased slightly with the addition of the fuels from the thinning. On the other hand, the surface fire potential decreased from 8 to 1, and available fuel potential decreased from 9 to 4 after the prescribed fire, as the surface woody fuels, litter, and duff were removed. Crown fire potential remained the same because the trees were not affected by the prescribed fire. This example shows how the FCCS fuelbed design enables a user to account for all fuelbed components by more accurately accounting for the critical fuelbed characteristics affecting fire behaviour, fire effects, and allowing improved assessment of fuel treatment effectiveness.

Because the fuelbed accounts for nearly all combustible biomass, FCCS can also be used to survey total carbon and provide the fuel input into models that estimate carbon flux into the atmosphere from wildland fires. This is important to improve our regional and global estimation of carbon emissions. For example, in 2002, the Biscuit wildfire burned over 200 000 ha of forested lands in southwestern Oregon. By using methods outlined in McKenzie et al. (2007), FCCS fuelbeds were assigned to the Biscuit wildfire landscape based on remotely sensed vegetation attributes. The fuel loading for all fuelbed strata, categories, and subcategories for each fuelbed assignment was tallied and divided by 50% (standard approximation of carbon content for pools of biomass). Total carbon for the area was calculated to be 13.3 Tg. Resulting fuel loadings were then input into Consume 3.0 (Anderson et al. 2006) using fuel moisture and other environmental conditions reported at the Biscuit fire. Total carbon emitted from the fire was estimated at about 5.1 Tg.

The fuelbed design used in FCCS is robust and allows users to capture all biomass that has the potential to consume. In addition, several hundred new fuelbeds are being constructed and reviewed for specific forest-scale projects in the United States, Canada, and Mexico. As new fuelbeds are added to the system, an improved naming nomenclature may be developed. Several fuelbed input requirements, such as litter arrangement and ladder fuel type, will need improved field quantification to better differentiate between these fuelbed subcategories within the system. In addition, pictures are worth a thousand words and the FCCS will eventually accommodate photographs that represent the internal or customized fuelbeds. Finally, work is underway to adapt the fuelbeds and FCCS to metric and for worldwide application.

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Appendix A

Appendix starts on the following page.

Table A1. Fuel Characteristic Classification System fuelbeds by geographic region.

Fuelbed identification No.	Fuelbed name	Change agent
Alaska		
85	Black spruce / lichen forest	None
86	Black spruce / feather moss forest	None
87	Black spruce / feather moss forest	None
88	Black spruce / sphagnum moss forest	None
89	Black spruce / sheathed cottongrass woodland	None
91	White spruce / prickly rose forest	None
92	Aspen – paper birch – white spruce – black spruce forest	None
93	Paper birch – trembling aspen forest	None
94	Balsam poplar – trembling aspen forest	None
95	Willow – alder shrubland	None
97	Cottongrass grassland	None
98	Marsh Labrador tea – lingonberry tundra shrubland	None
99	Bluejoint reedgrass grassland	None
100	Altai fescue grassland	None
101	White spruce forest	None
102	White spruce forest	Insects and disease
103	White spruce – paper birch forest	None
104	White spruce – paper birch forest	Insects and disease
105	Paper birch – trembling aspen – white spruce forest	None
Hawaii		
71	Ohia / Florida hopbush – kupaoa forest	None
72	Ohia / uluhe forest	None
73	Koa / pukiawe forest	None
74	Mamani – naio savanna	None
75	Slash pine / New Caledonia pine forest	Introduction of exotic species
76	Slash pine / molassesgrass forest	Introduction of exotic species
77	Eucalyptus plantation forest	Introduction of exotic species
78	Florida hopbush – Mauna Loa beggarticks shrubland	None
79	Pili grass – broomsedge bluestem grassland	Grazing, introduction of exotic species
80	Fountain grass grassland	Introduction of exotic species
81	Columbia bluestem / pukiawe grassland	Introduction of exotic species
82	White leadtree / guineagrass shrubland	Introduction of exotic species
83	Molassesgrass grassland	Introduction of exotic species
84	Ohia / broomsedge bluestem savanna	Introduction of exotic species
260	Ohia / uluhe forest	Wildfire
261	Pili grass – broomsedge bluestem grassland	Wildfire
262	Molassesgrass grassland	Wildfire
263	Ohia / broomsedge bluestem savanna	Wildfire
Northeast		
106	Red spruce – balsam fir forest	Insects and disease
107	Pitch pine / scrub oak forest	Fire exclusion; none
109	Eastern white pine – northern red oak – red maple forest	Fire exclusion; none
110	American beech – yellow birch – sugar maple forest	Selection cut
124	Pitch pine – oak forest	None
125	Oak – hickory – pine – eastern hemlock forest	None
138	Red pine – white pine forest	Fire exclusion
140	Jack pine / black spruce forest	Fire exclusion
142	Trembling aspen – paper birch forest	None
146	Jack pine forest	None
147	Jack pine savanna	None
148	Jack pine forest	Wildfire
152	Red pine – white pine forest	Windthrow
155	Red spruce – balsam fir forest	None
243	Pitch pine / scrub oak shrubland	Wildfire

Table A1 (*continued*).

Fuelbed identification No.	Fuelbed name	Change agent
267	American beech – yellow birch – sugar maple – red spruce forest	None
274	American beech – sugar maple forest	None
279	Black spruce – northern white-cedar – larch forest	None
287	Eastern white pine – eastern hemlock forest	None
Pacific Northwest		
1	Black cottonwood – Douglas-fir – quaking aspen riparian forest	None
2	Western hemlock – western redcedar – Douglas-fir forest	None
3	Douglas-fir forest	Thinning
4	Douglas-fir / *Ceanothus* forest	Prescribed fire; clearcut
5	Douglas-fir – white fir forest	Fire exclusion
6	Oregon white oak – Douglas-fir forest	Selection cut
7	Douglas-fir – sugar pine – tanoak forest	Fire exclusion
8	Western hemlock – Douglas-fir – western redcedar / vine maple forest	None
9	Douglas-fir – western hemlock – western redcedar / vine maple forest	Clearcut
10	Western hemlock – Douglas-fir – Sitka spruce forest	None
11	Douglas-fir / western hemlock – Sitka spruce forest	Clearcut
13	Mountain hemlock – Pacific silver fir forest	Wildfire
18	Douglas-fir / oceanspray forest	Prescribed fire
24	Pacific ponderosa pine – Douglas-fir forest	Fire exclusion; grazing
38	Douglas-fir – madrone / tanoak forest	Fire exclusion
39	Sugar pine – Douglas-fir – oak forest	None
41	Fescue – wheatgrass grassland	Fire exclusion; grazing
52	Douglas-fir – Pacific ponderosa pine / oceanspray forest	Fire exclusion
53	Pacific ponderosa pine forest	Fire exclusion; insects and disease
54	Douglas-fir – white fir – interior ponderosa pine forest	Fire exclusion
62	*Vaccinium* – heather shrublands	Wildfire
63	Showy sedge – alpine black sedge grassland	None
208	Grand fir – Douglas-fir forest	Fire exclusion
212	Pacific ponderosa pine forest	Selection cut
215	Douglas-fir – madrone / tanoak forest	Wildfire
221	Wheatgrass – ryegrass grassland	Prescribed fire; restoration work
235	Idaho fescue – bluebunch wheatgrass grassland	Wildfire
237	*Vaccinium* – heather shrublands	None
238	Pacific silver fir – mountain hemlock forest	None
239	Douglas-fir – sugar pine – tanoak forest	Wildfire
Rocky Mountain and central United States		
21	Lodgepole pine forest	Wildfire
22	Lodgepole pine forest	None
23	Lodgepole pine forest	Insects and disease
26	Interior ponderosa pine – limber pine forest	Fire exclusion
28	Ponderosa pine savanna	None; wildfire
42	Trembling aspen / Engelmann spruce forest	Fire exclusion
56	Sagebrush shrubland	Fire exclusion; grazing; introduction of exotic species
57	Wheatgrass – cheatgrass grassland	Grazing; introduction of exotic species
58	Western juniper / sagebrush savanna	Prescribed fire
59	Subalpine fir – Engelmann spruce – Douglas-fir – lodgepole pine forest	None
60	Sagebrush shrubland	Prescribed fire
61	Whitebark pine / subalpine fir forest	Insects and disease
66	Bluebunch wheatgrass – bluegrass grassland	None
67	Interior ponderosa pine – Douglas-fir forest	Fire exclusion
69	Western juniper / sagebrush – bitterbrush shrubland	Fire exclusion
70	Subalpine fir – lodgepole pine – whitebark pine – Engelmann spruce forest	Fire exclusion
90	White oak – northern red oak forest	None
143	Trembling aspen – paper birch – white spruce – balsam fir forest	None
154	Bur oak savanna	Fire exclusion

Table A1 (*continued*).

Fuelbed identification No.	Fuelbed name	Change agent
210	Pinyon – juniper woodland	Fire exclusion; grazing
213	Wheatgrass – cheatgrass grassland	Introduction of exotic species; prescribed fire
224	Trembling aspen forest	Fire exclusion
225	Trembling aspen forest	Prescribed fire
228	Interior ponderosa pine – limber pine forest	Prescribed fire
265	Balsam fir – white spruce – mixed hardwoods forest	None
266	Sugar maple – basswood forest	None
268	American beech – yellow birch – sugar maple – eastern hemlock forest	None
284	Green ash – American elm – silver maple – cottonwood forest	Insects and disease; none
286	Interior ponderosa pine – limber pine forest	Fire exclusion
Sierra Nevada		
12	Red fir – mountain hemlock – lodgepole pine – white pine forest	None
14	Black oak woodland	None
15	Jeffrey pine – red fir – white fir / greenleaf manzanita – snowbrush forest	Fire exclusion; selection cut
16	Jeffrey pine – ponderosa pine – Douglas-fir – black oak forest	Fire exclusion
17	Red fir forest	Fire exclusion
19	White fir – giant sequoia – sugar pine forest	Fire exclusion
20	Western juniper / mountain mahogany woodland	Fire exclusion
36	Live oak – blue oak woodland	Fire exclusion; grazing
37	Ponderosa pine – Jeffrey pine forest	Fire exclusion; grazing
44	Scrub oak – chaparral shrubland	None
46	Chamise chaparral shrubland	None
47	Redwood – tanoak forest	Fire exclusion
48	Douglas-fir – tanoak – madrone – California bay forest	None
51	Coastal sage shrubland	None
65	Purple tussockgrass – California oatgrass grassland	Fire exclusion; grazing
214	Giant sequoia – white fir – sugar pine forest	Prescribed fire
Southeast		
114	Virginia pine – pitch pine – shortleaf pine forest	Fire exclusion
115	Rhododendron – blueberry – mountain laurel shrubland	None
120	Oak – pine / mountain laurel forest	Fire exclusion
121	Oak – pine / mountain laurel forest	Insects and disease
123	White oak – northern red oak – black oak – hickory forest	Fire exclusion
129	Green ash – American elm forest	Insects and disease
131	Bluestem – indiangrass – switchgrass grassland	Prescribed fire
133	Tall fescue – foxtail – purple bluestem grassland	Introduction of exotic species
134	White oak – northern red oak – hickory forest	Clearcut
135	Eastern redcedar – oak / bluestem savanna	None
156	Slash pine plantation forest	Thinning
157	Loblolly pine – shortleaf pine – mixed hardwoods forest	None
158	Loblolly pine – shortleaf pine – mixed hardwoods forest	Insects and disease
161	Loblolly pine – slash pine forest	None
162	Loblolly pine – slash pine forest	Thinning
164	Sand pine forest	None
165	Longleaf pine / three-awned grass – pitcher plant savanna	Prescribed fire
166	Longleaf pine / three-awned grass – pitcher plant savanna	Fire exclusion
168	Little gallberry – fetterbush shrubland	None
170	Pond pine / little gallberry – Fetterbush shrubland	None
173	Live oak / sea oats savanna	None
174	Live oak – sabal palm forest	None
175	Smooth cordgrass – black needlerush grassland	None
176	Smooth cordgrass – black needlerush grassland	Introduction of exotic species
178	Loblolly pine – shortleaf pine forest	Clearcut
180	Red maple – oak – hickory – sweetgum forest	Selection cut
181	Pond pine forest	None

Table A1 (*continued*).

Fuelbed identification No.	Fuelbed name	Change agent
182	Longleaf pine – slash pine / saw palmetto – gallberry forest	Fire exclusion
183	Loblolly pine – shortleaf pine forest	Thinning
184	Longleaf pine / turkey oak forest	Fire exclusion
185	Longleaf pine / turkey oak forest	Prescribed fire
186	Turkey oak – bluejack oak forest	Fire exclusion
187	Longleaf pine / yaupon forest	Thinning
188	Sand pine – oak forest	None
189	Sand pine – oak forest	Insects and disease
190	Slash pine – longleaf pine / gallberry forest	Fire exclusion
191	Longleaf pine – slash pine / gallberry forest	Prescribed fire
196	Loblolly pine / bluestem forest	Clearcut
203	Sawgrass – *Muhlenbergia* grassland	None
240	Saw palmetto / three-awned grass shrubland	Fire exclusion; clearcut
241	Longleaf pine – loblolly pine forest	Windthrow
242	Longleaf pine – loblolly pine forest	Prescribed fire
264	Post oak – blackjack oak forest	Fire exclusion, grazing
269	Sugar maple – yellow poplar – American beech – oak forest	None
270	Red spruce – Fraser fir / rhododendron forest	Insects and disease; windthrow
272	Red mangrove – black mangrove forest	None
275	Chestnut oak – white oak – red oak forest	Fire exclusion
276	Oak – pine – magnolia forest	Fire exclusion
280	Bluestem – gulf cordgrass grassland	Fire exclusion
281	Shortleaf pine – post oak – black oak forest	Fire exclusion
282	Loblolly pine forest	None
283	Willow oak – laurel oak – water oak forest	None
288	Bald-cypress – water tupelo forest	None
289	Pond-cypress / *Muhlenbergia* – Sawgrass savanna	None
291	Longleaf pine – slash pine / saw palmetto forest	Fire exclusion
Southwest		
25	Pinyon – juniper forest	Fire exclusion; grazing
27	Ponderosa pine – two-needle pinyon – Utah juniper forest	Fire exclusion
29	Interior ponderosa pine – Engelmann spruce – Douglas-fir forest	Selection cut
30	Turbinella oak – mountain mahogany shrubland	None
32	Ponderosa pine / pinyon pine – juniper forest	Fire exclusion; grazing
33	Gambel oak / sagebrush shrubland	Wildfire
34	Interior Douglas-fir – interior ponderosa pine / Gambel oak forest	Fire exclusion
40	Tobosa – Grama grassland	Grazing; introduction of exotic species
43	Arizona white oak – gray oak – Emory oak woodland	Fire exclusion; grazing
45	Pine – oak forest	Fire exclusion; grazing
49	Creosote bush shrubland	Fire exclusion; grazing
55	Western juniper / sagebrush savanna	Fire exclusion
211	Interior ponderosa pine forest	Fire exclusion
216	Gambel oak – bigtooth maple forest	Fire exclusion
217	Gambel oak – bigtooth maple forest	Prescribed fire
218	Gambel oak / sagebrush shrubland	Fire exclusion
219	Ponderosa pine – white fir / trembling aspen forest	Fire exclusion
220	Ponderosa pine – white fir / trembling aspen forest	Prescribed fire
222	Interior ponderosa pine forest	Prescribed fire
223	Douglas-fir – white fir – interior ponderosa pine forest	Wildfire
226	White fir – Gambel oak forest	Fire exclusion
227	White fir forest	Prescribed fire
229	Ponderosa pine / juniper forest	Prescribed fire
230	Pinyon – juniper forest	Prescribed fire
231	Gambel oak – juniper – ponderosa pine forest	Fire exclusion; grazing
232	Mesquite savanna	Fire exclusion; grazing
233	Sagebrush shrubland	Fire exclusion

Table A1 (*concluded*).

Fuelbed identification No.	Fuelbed name	Change agent
234	Sagebrush shrubland	Prescribed fire
236	Tobosa – Grama grassland	None
273	Engelmann spruce – Douglas-fir – white fir – interior ponderosa pine forest	Fire exclusion

Note: Fuelbeds are not sequential and there are some gaps.

Table A2. Common and scientific names of species used to name fuelbeds in the Fuel Characteristic Classification System.

Common name	Scientific Name
Alderleaf mountain mahogany	*Cercocarpus montanus* Raf.
Black alpinesedge	*Carex nigricans* C.A. Mey.
Altai fescue	*Festuca altaica* Trin.
American beech	*Fagus grandifolia* Ehrh.
American elm	*Ulmus americana* L.
Arizona white oak	*Quercus arizonica* Sarg.
Aspen	*Populus*
Bald-cypress	*Taxodium distichum* (L.) L. Rich.
Balsam fir	*Abies balsamea* (L.) Mill.
Balsam poplar	*Populus balsamifera* L.
Basswood	*Tilia americana* L.
Big sagebrush	*Artemisia tridentata* Nutt.
Bigtooth maple	*Acer grandidentatum* Nutt.
Antelope bitterbrush	*Purshia tridentata* (Pursh) DC.
Black cottonwood	*Populus balsamifera* ssp. *trichocarpa* (Torr. & Gray ex Hook.) Brayshaw
Black mangrove	*Avicennia germinans* (L.) L.
Black needlerush	*Juncus roemerianus* Scheele
Black oak	*Quercus velutina* Lam.
Black spruce	*Picea mariana* (Mill.) BSP
Blackjack oak	*Quercus marilandica* (L.) Muenchh.
Blue oak	*Quercus douglasii* Hook. & Arn.
Blueberry	*Vaccinium* L. spp.
Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) Á. Löve
Kentucky bluegrass	*Poa pratensis* L.
Bluejack oak	*Quercus incana* Bartr.
Bluejoint reedgrass	*Calamagrostis canadensis* (Michx.) Beauv.
Big bluestem	*Andropogon gerardii* Vitman
Broomsedge bluestem	*Andropogon virginicus* L.
Bur oak	*Quercus macrocarpa* Michx.
California bay	*Umbellularia californica* (Hook. & Arn.) Nutt.
California black oak	*Quercus kelloggii* Newberry
California live oak	*Quercus agrifolia* Née
California oatgrass	*Danthonia californica* Boland.
Ceanothus	*Ceanothus* L.
Chamise	*Adenostoma fasciculatum* Hook. & Arn.
Cheatgrass	*Bromus tectorum* L.
Chestnut oak	*Quercus prinus* L.
Coastal sage	*Artemisia californica* Less.
Colombian bluestem	*Schizachyrium condensatum* (Kunth) Nees
Cottongrass	*Eriophorum vaginatum* L.
Eastern cottonwood	*Populus deltoides* Bartr. ex Marsh.
Creosote bush	*Larrea tridentata* (Sessé & Moc. ex DC.) Cov.
Curl-leaf mountain mahogany	*Cercocarpus ledifolius* Nutt.
Douglas-fir	*Pseudotsuga menziesii* (Mirb) Franco var. *menziesii*
Eastern hemlock	*Tsuga canadensis* (L.) Carrière
Eastern redcedar	*Juniperus virginiana* L.
Eastern white pine	*Pinus strobus* L.

Table A2 (*continued*).

Common name	Scientific Name
Emory oak	*Quercus emoryi* Torr.
Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
Eucalyptus	*Eucalyptus* spp. L'Hér.
Feather moss	*Hylocomium splendens* (Hedw.) Schimp. in B.S.G.
Fetterbush	*Lyonia lucida* (Lam.) K. Koch
Florida hopbush	*Dodonaea viscosa* (L.) Jacq.
Crimson Fountain grass	*Pennisetum setaceum* (Forssk.) Chiov.
Foxtail	*Setaria* Beauv. spp.
Fraser fir	*Abies fraseri* (Pursh) Poir.
Gallberry	*Ilex glabra* (L.) Gray
Gambel oak	*Quercus gambelii* Nutt.
Giant sequoia	*Sequoiadendron giganteum* (Lindl.) Buchh.
Grama	*Bouteloua* Lag. spp.
Grand fir	*Abies grandis* (Dougl. ex D. Don)
Gray oak	*Quercus grisea* Liebm.
Green ash	*Fraxinus pennsylvanica* Marsh.
Greenleaf manzanita	*Arctostaphylos patula* Greene
Guineagrass	*Urochloa maxima* (Jacq.) R, Webster
Gulf cordgrass	*Spartina spartinae* (Trin.) Merr. ex A.S. Hitchc.
Heather	*Cassiope mertensiana* (Bong.) G. Don
Hickory	*Carya* Nutt. spp.
Idaho fescue	*Festuca idahoensis* Elmer
Indiangrass	*Sorghastrum nutans* (L.) Nash
Interior Douglas-fir	*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco
Interior ponderosa pine	*Pinus ponderosa* Dougl. ex P. & C. Laws.
Jack pine	*Pinus banksiana* Lamb.
Jeffrey pine	*Pinus jeffreyi* Grev. & Balf.
Koa	*Acacia koa* Gray
Kupaoa	*Dubautia ciliolata* (DC.) Keck
Larch	*Larix laricina* (Du Roi) K. Koch
Laurel oak	*Quercus laurifolia* Michx.
Lichen	*Cladonia* spp.
Limber pine	*Pinus flexilis* James
Lingonberry	*Vaccinium vitis-idaea* L.
Live oak	*Quercus virginiana* P. Mill.
Loblolly pine	*Pinus taeda* L.
Lodgepole pine	*Pinus contorta* Dougl. ex Loud. var latifolia Engelm.
Longleaf pine	*Pinus palustris* P. Mill.
Pacific madrone	*Arbutus menziesii* Pursh
Southern magnolia	*Magnolia grandiflora* L.
Mamani	*Sophora chrysophylla* (Salisb.) Seem.
Marsh Labrador tea	*Ledum palustre* ssp. *decumbens* (Ait.) Hultén
Mauna Loa beggarticks	*Bidens menziesii* (Gray) Sherff
Honey mesquite	*Prosopis glandulosa* Torr.
Mixed hardwoods	Various species
Molassesgrass	*Melinis minutiflora* Beauv.
Mountain alder	*Alnus viridis* ssp. *crispa* (Ait.) Turrill
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carrière
Mountain laurel	*Kalmia latifolia* L.
Muhlenbergia	*Muhlenbergia filipes* M.A. Curtis
Naio	*Myoporum sandwicense* (A. DC.) Gray
New Caledonia pine	*Araucaria columnaris* (Forster) Hook.
Northern red oak	*Quercus rubra* L.
Northern white-cedar	*Thuja occidentalis* L.
Oak	*Quercus* L. spp.
Oceanspray	*Holodiscus discolor* (Pursh) Maxim.
Ohia	*Metrosideros polymorpha* Gaud.

Table A2 (*continued*).

Common name	Scientific Name
Oregon white oak	*Quercus garryana* Dougl. ex Hook.
Pacific ponderosa pine	*Pinus ponderosa* P. & C. Laws. var. *ponderosa*
Pacific silver fir	*Abies amabilis* (Dougl. ex Loud.) Dougl. ex Forbes
Paper birch	*Betula papyrifera* Marsh.
Pili grass	*Heteropogon contortus* (L.) Beauv. ex Roemer & J.A. Schultes
Pine	*Pinus* L. spp.
Pinyon	*Pinus edulis* Engelm.
Pinyon pine	*Pinus edulis* Engelm.
Pitch pine	*Pinus rigida* Mill.
Pitcherplant	*Sarracenia* L. spp.
Pond pine	*Pinus serotina* Michx.
Pond-cypress	*Taxodium ascendens* Brongn.
Ponderosa pine	*Pinus ponderosa* Dougl. ex P. & C. Laws.
Post oak	*Quercus stellata* Wangenh.
Prickly rose	*Rosa acicularis* Lindl.
Pukiawe	*Styphelia tameiameiae* (Cham. & Schlecht.) F. Muell.
Purple bluestem	*Andropogon glaucopsis* Ell.
Purple tussockgrass	*Nassella pulchra* (A.S. Hitchc.) Barkworth
Quaking aspen	*Populus tremuloides* Michx.
Red fir	*Abies magnifica* A. Murr.
Red mangrove	*Rhizophora mangle* L.
Red maple	*Acer rubrum* L.
Red pine	*Pinus resinosa* Ait.
Red spruce	*Picea rubens* Sarg.
Redwood	*Sequoia sempervirens* (Lamb. ex D. Don) Endl.
Rhododendron	*Rhododendron* L. spp.
Rocky Mountain juniper	*Juniperus scopulorum* Sarg.
Ryegrass	*Leymus cinereus* (Scribn. & Merr.) ex Á. Löve
Sabal palm	*Sabal palmetto* (Walt.) Lodd. ex J.A. & J.H. Schultes
Sagebrush	*Artemisia* L. spp.
Sand pine	*Pinus clausa* (Chapman ex Engelm.) Vasey ex Sarg.
Saw palmetto	*Serenoa repens* (Bartr.) Small
Sawgrass	*Cladium mariscus* ssp. *jamaicense* (Crantz) K kenth.
Scrub oak	*Quercus berberidifolia* Liebm.
Scrub oaks	*Quercus* L. spp.
Sea oats	*Uniola paniculata* L.
Shortleaf pine	*Pinus echinata* P. Mill.
Showy sedge	*Carex spectabilis* Dewey
Silver maple	*Acer saccharinum* L.
Sitka spruce	*Picea sitchensis* (Bong.) Carriére
Slash pine	*Pinus elliottii* Engelm.
Smooth cordgrass	*Spartina alterniflora* Loisel.
Snowbrush	*Ceanothus velutinus* Dougl. ex Hook.
Sphagnum moss	*Sphagnum* L. spp.
Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
Sugar maple	*Acer saccharum* Marsh.
Sugar pine	*Pinus lambertiana* Dougl.
Sweetgum	*Liquidambar styraciflua* L.
Switchgrass	*Panicum virgatum* L.
Tall fescue	*Lolium arundinaceum* (Schreb.) S.J. Darbyshire
Tanoak	*Lithocarpus densiflorus* (Hook. & Arn.) Rehd.
Three-awned grass	*Aristida* L. spp.
Tobosa	*Hilaria mutica* (Buckl.) Benth.
Trembling aspen	*Populus tremuloides*
Turbinella oak	*Quercus turbinella* Greene
Turkey oak	*Quercus laevis* Walt.
Two-needle pinyon	*Pinus edulis*

Table A2 (*concluded*).

Common name	Scientific Name
Uluhe	*Dicranopteris emarginata* (T. Moore) W.J. Robins.
Utah juniper	*Juniperus osteosperma* (Torr.) Little
Vaccinium	*Vaccinium* L. spp.
Vine maple	*Acer circinatum* Pursh
Virginia pine	*Pinus virginiana* P. Mill.
Water oak	*Quercus nigra* L.
Water tupelo	*Nyssa aquatica* L.
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
Western juniper	*Juniperus occidentalis* Sarg.
Western redcedar	*Thuja plicata* Donn ex D. Don
Western white pine	*Pinus monticola* Dougl. ex D. Don
Wheatgrass	*Pseudoroegneria spicata* (Pursh) Á. Löve
White fir	*Abies concolor* (Gord. & Glend.)
White leadtree	*Leucaena leucocephala* (Lam.) de Wit
White oak	*Quercus alba* L.
White spruce	*Picea glauca* (Moench) Voss
Whitebark pine	*Pinus albicaulis* Engelm.
Willow	*Salix* L. spp.
Willow oak	*Quercus phellos* L.
Yaupon	*Ilex vomitoria* Ait.
Yellow birch	*Betula alleghaniensis* Britt.
Yellow poplar	*Liriodendron tulipifera* L.