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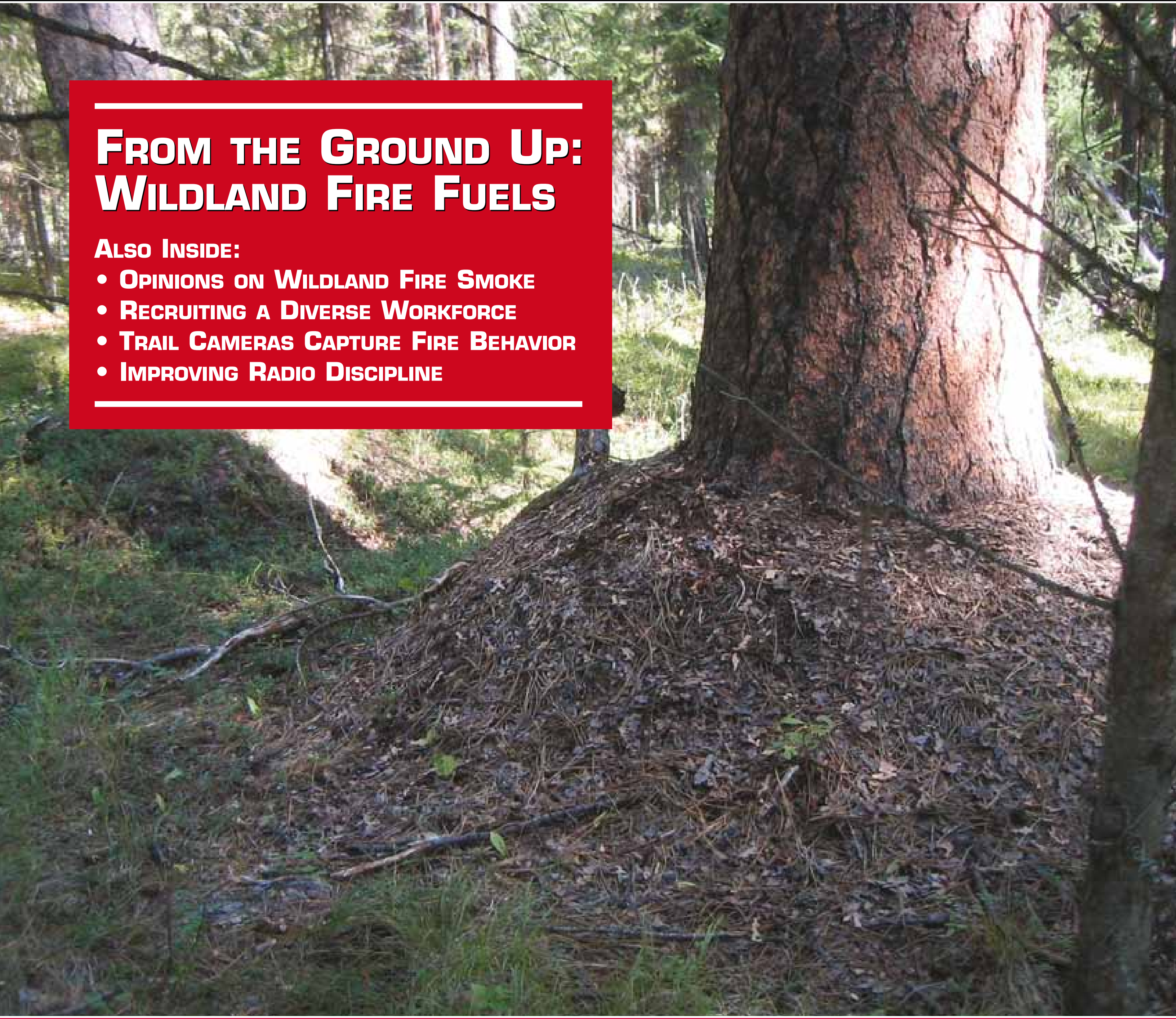

From the Ground Up: Wildland Fire Fuels

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Characterizing Hand-Piled Fuels

Clinton S. Wright, Paige C. Eagle, and Cameron S. Balog

The Hand-Piled Fuels Biomass Calculator is available at <http://depts.washington.edu/nwfire/handpiles>.

Land managers throughout the West pile and burn surface fuels to mitigate fire hazard in dry forests. Whereas piling was historically conducted with heavy machinery following commercial harvesting operations, land managers are increasingly prescribing the use of hand piling and burning to treat surface fuels created by thinning and brush cutting. An estimate of the weight of the piled debris to be burned is necessary to assess potential smoke emissions and air quality impacts associated with this practice.

How Much Fuel Is in This Pile?

It is impractical to weigh piled fuels, so methods have been developed to estimate weight from pile dimensions and other characteristics. Data are available for characterizing large, machine-constructed piles (Hardy 1996; Johnson 1984; Little 1982; McNab 1980, 1981; McNab and Saucier 1980), but not hand-constructed piles. Research to quantify the amount of woody debris in machine piles (Hardy 1996) is incorporated into the fire and fuel management decision support software application CONSUME 3.0 (Prichard and others, no date) and the Washington State Department of Natural Resources (DNR) online calculator (Alexander 2007; <http://www.dnr.wa.gov/RecreationEducation/Topics/FireBurningRegulations/Pages/rp_burn_tonnagecalculator.htm>) .

> Tools and applications developed for describing machine piles may overestimate the amount of fuel in hand piles.

Differences in structure and composition between hand and machine piles, however, result in different relationships between pile dimensions, pile volume, and pile weight, so tools and applications developed for describing machine piles are likely to mis-characterize hand piles. To address this issue, we measured and weighed hand piles to document the relationships between easily measured variables and fuel loading and incorporated this information into the Hand-Piled Fuels Biomass Calculator, a

Slash is often piled by hand and later burned as a surface fuel treatment to mitigate potential negative impacts of broadcast burning and to reduce fire hazard. Photo: Ernesto Alvarado, University of Washington, Seattle.

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simple online calculator specifically for characterizing the relationship between hand pile dimensions, volume, and weight.

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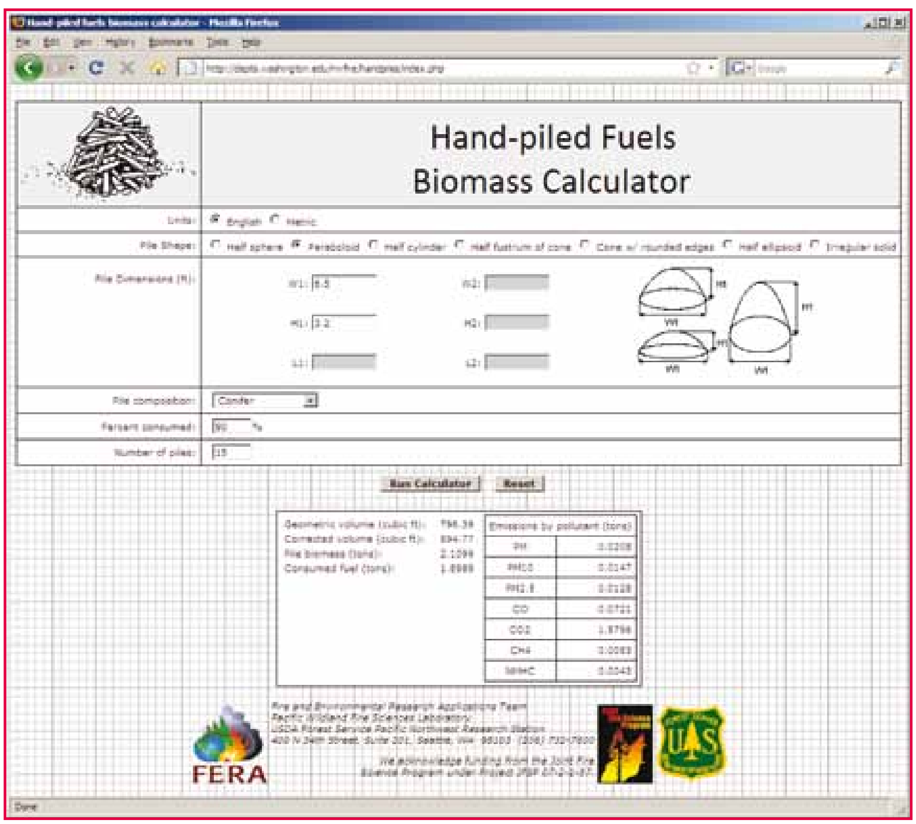
The equations in the calculator are based on measurements of the dimensions, volume, and weight of 121 hand piles composed primarily of coniferous (n=63) and shrub/hardwood (n=58) material located in Washington and California. Equations using pile dimensions, shape, and type allow users to more accurately estimate the volume and weight of hand piles for regulatory reporting and smoke-management planning (Wright and others 2010).

Calculating Emissions

Calculating emissions from pile burning is a five-step process:

1. Measure pile dimensions and calculate pile volume;
2. Assess the pile composition (conifer or shrub/hardwood debris);
3. Calculate the weight of fuel in the pile using equations that relate pile volume to pile weight;
4. Calculate consumable fuel weight (pile weight × percentage of expected consumption = consumable fuel weight); and
5. Apply an emission factor (consumable fuel weight × emission factor = emissions) to estimate potential emissions.



The online calculator allows the user to estimate the volume and weight of hand-piled fuels according to the shape selected and the entered dimensions. Potential emissions of different pollutants are calculated based on the calculated weight, emission factors, and user-specified consumption proportions.

Pile volume and fuel weight

A potentially large portion of the error associated with estimating pollutant emissions from fire is related to difficulties and inaccuracies in characterizing fuel weight or loading (Peterson and Sandberg 1988). In the calculator, users select a geometric shape that best represents their pile or piles and enter the measured dimensions required for that pile shape. These inputs are used to calculate the volume of the pile based on specific geometric formulas. Pile volume determined from pile dimensions and geometric formulas (geometric pile volume) is not perfectly correlated with true pile volume, so the calculator applies an empirically derived adjustment to the geometric volume, resulting in a more accurate estimate. Adjusted or true pile volume is then used as a predictor to estimate pile weight for different pile types (that is, piles composed primarily of coniferous debris or piles composed primarily of shrub and hardwood debris).

Estimating Consumable Fuel

CONSUME 3.0 assumes that 90 percent of piled fuels are consumed during a burning operation based on observations of 75–95 percent consumption reported by Hardy (1996). Hardy observed consumption in machine pile burns; no studies that we know of have documented the fuel consumption when hand piles are burned, although we expect hand piles to burn in a manner similar to machine-piles, in which most, if not all, of the piled debris is consumed. Users can adjust the estimated percentage consumption when hand piles are burned under conditions that are expected to reduce fuel consumption, such as in wet or snowy conditions.

Adjusting Emission

The amount of soil that is mixed into a pile when it is constructed affects the amount of smoke that is produced during burning. Soil contamination reduces combustion efficiency and effectively increases the emissions of airborne pollutants that are produced for each increment of fuel that is consumed. Machine piles can contain significant quantities of mineral soil depending upon the soil conditions at the time of piling and the skill of the equipment operator who constructed the pile. Hand piles, on the other hand, are virtually free of soil contamination and, therefore, burn more efficiently, producing fewer pollutants for each increment of fuel that is consumed. Hardy (1996) provides emission factors for total particulate matter (PM), particulate matter less than 10 micrometers in mean diameter (PM_{10}), and particulate matter less than 2.5 micrometers in mean diameter ($PM_{2.5}$) from the burning of piled fuels with differing levels of combustion efficiency related to differing levels of soil contamination. Using a combustion efficiency of 0.91 for "clean" piles yields emission factors of 13.5, 15.5, and 21.9 pounds of emissions per ton of fuel consumed (6.75, 7.75, and 10.95 kg per metric ton) for $PM_{2.5}$, PM_{10}, and PM, respectively. Assuming that 70 percent of consumption occurs during the flaming phase of combustion and that 15 percent occurs during each of the smoldering and residual phases of combustion, emission factors for carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), and nonmethane hydrocarbons (NMHC) are 152.0, 3,327.4, 11.2, and 9.0 pounds per ton (76.0, 1,663.8, 5.6, and 4.5 kg per metric ton), respectively (Prichard and others, no date). Multiplying fuel weight consumed by the above-listed emission factors yields the weight of pollutant emissions.

Looking ahead, we would like to improve this tool so that users will have a single resource for characterizing piles of any type.

Looking Ahead

We designed the initial version of this online calculator specifically for estimating the volume and weight of hand-piled fuels. This tool complements CONSUME 3.0 and the Washington DNR calculator that address machine-piles. It enables fire managers and air-quality regulators to more accurately estimate fuel consumption and emissions for hand piles. Looking ahead, we would like to improve the functionality of this tool by integrating the algorithms for estimating machine pile weight, consumption, and emissions into a future version so that users will have a single resource for characterizing piles of any type.

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