Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

Hand-piled fuels after thinning near Naches, WA, a sample area. Credit: Clint Wright.

A New Online Tool and Estimates for Hand-Pile Biomass and Smoke Production

Summary

To help reduce the chance for high-severity fires in the western United States, thinning of the forest understory, midstory and overstory has become a necessity. In some cases, the resulting surface fuels are piled by hand and burned. As this two-part treatment method becomes more widely-used, fire managers need the ability to calculate the biomass of hand-piled fuels so they can better estimate the potential emissions and smoke impacts from their disposal by burning. Since machine-constructed piles were sampled in a previous study, researchers were able to use this past research as a point of departure to develop methods to better characterize the biomass of hand-constructed piles. The research team measured and weighed hand piles to improve the accuracy of volume, weight and emissions estimates. The compiled data were incorporated into a simple online calculator which provides fuel and fire managers with the ability to estimate smoke production with a few basic observations and measurements.

Key Findings

- Composition of machine- and hand-constructed piles is different.
- The use of standard geometric volume formulas tends to overestimate the true volume of hand piles.
- Managers need not know wood density or packing ratio to estimate hand pile biomass.
- Estimates of hand pile biomass can be made using an online calculator at: http://depts.washington.edu/nwfire/handpiles.
- Improved data make compliance with air quality regulations more effective, as managers can easily calculate emissions estimates upon which to base decisions about how many piles to burn and when.

Building on past research

In the mid-1990s, Colin Hardy completed a project that characterized the biomass of machine-constructed piles and their emissions when burned. The calculations used in Hardy's research have been integrated into the CONSUME fuel and fire management decision-support software. Using the earlier work by Hardy as a jumping off point, researchers from the Forest Service's Pacific Wildland Fire Sciences Laboratory focused on investigating the biomass of hand piles, with the intention of incorporating the results into CONSUME.

One goal, many methods

As fuels accumulate beyond historical natural levels, land managers employ fuel-reduction treatments to help reduce fire hazard and restore ecosystems. It is evident that as land managers utilize these different methods they are discovering that some work better than others for certain conditions. One common approach is the use of mechanical treatments such as brush cutting and thinning from below. While these mechanical methods can help reshape forest fuel profiles and reduce the potential for catastrophic fire, they can also leave behind a significant amount of surface fuel.

Another common landscape treatment is prescribed burning, a traditional method used to reduce or remove understory vegetation and surface fuels created during mechanical operations. This method has become more complex and difficult to perform as fuel levels and air quality restrictions rise and treatments are performed in close proximity to populated areas.

Piling by hand and burning the piled slash is a fuel-reduction method that is being applied more frequently in forest and woodland types. Typically used as a follow-up treatment to mechanical thinning, hand piling and burning removes surface fuels to mitigate fire risk. Compared to machine-constructed piles, hand piles are relatively small and can be burned with minimal staff. Because of the level of control fire managers have when burning piles, they can be burned in close proximity to higher risk areas such as roads and dwellings, in sensitive air sheds, and under weather and fuel-moisture conditions that are not conducive for broadcast prescribed burning.

Seven stands, four sites, and 121 piles

As hand piling and burning becomes a more popular fuel-reduction treatment for high fire hazard areas with heavy surface fuels, managers need the ability to determine the biomass of hand piles so they can provide more precise smoke estimates and ensure compliance with Federal and State air quality regulations.

As mentioned earlier, information on the physical characteristics of larger, machine-constructed piles was collected in a previous study; a goal of this project was to extend and complement this past research to quantify the relationships between the composition, size, and biomass of hand-constructed piles. Seven stands at four sample sites in Washington and California were selected that represented typical hand piling and surface fuel treatments in the West.

Composed primarily of coniferous, shrub and hardwood material, 121 hand-constructed piles of various sizes were measured for volume, dimensions and biomass. Most piles were modest in size, measuring approximately an average of 100 cubic feet and weighing an average of 345 pounds, with the largest pile measuring roughly 500 cubic feet and the heaviest pile weighing almost 1,500 pounds.

Measuring a hand pile in the field to determine biomass. Credit: Clint Wright.

Models that require only simple measurements and observations are incorporated into an easy-to-use online calculator that returns volume, biomass, and potential emissions estimates for hand piles. This tool is similar to the calculator in CONSUME and the online calculator developed by the Washington Department of Natural Resources for machine piles (http://www.dnr.wa.gov/RecreationEduction/Topics/FireBurningRegulations/Pages/rp_burn_tonnagecalculator.htm).

Clint Wright, one of the principal investigators on the project, noted, “Estimates of biomass and predictions of emissions can be used to make go-no-go decisions regarding how many piles to burn at one time or when to burn to allow adequate dispersion of the smoke that is expected.”

Studying pile characteristics and composition

It may appear that all piles are the same. However, whether constructed by hand or machine, the physical properties of piles can vary considerably, from the size of limbs and fuel particles to the amount of air and mineral soil in the pile. Because of these variables, it is important for land and fuel managers to consider how each pile is constructed—and of what it is constructed—before trying to characterize biomass and potential emissions.

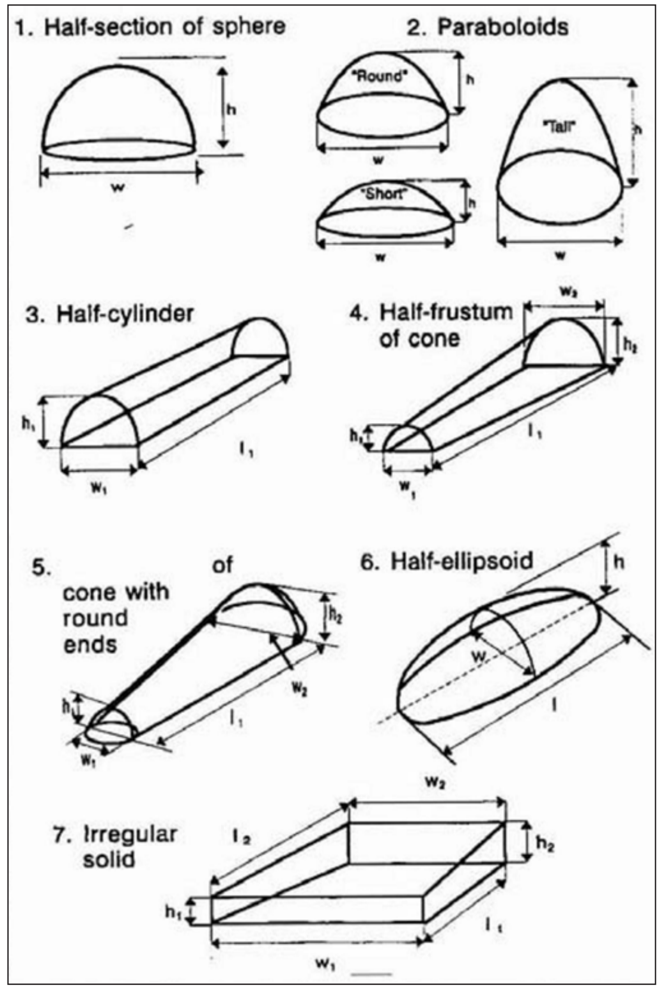
Machine-constructed piles are generally larger in size and typically have bigger fuel particles such as bulky limbs, tree tops, and stumps. Also, if the pile is not mechanically compacted or neatly stacked, a large amount of air and soil may be included in the overall pile volume.

In contrast, hand-constructed piles tend to be smaller in size than machine-constructed piles, with smaller fuel particles such as twigs, needles and leaves, and little stems and branches. This smaller size can provide greater flexibility when working within close proximity to populated and developed areas. Since hand-constructed piles are built with human labor, they tend to have less soil contamination, resulting in more efficient combustion and less smoke when burned.

Another factor that contributes to the differences in biomass is pile composition. While the wood of shrubs and hardwoods may be more dense than that of conifers, what appears to be the most important factor affecting the relationship between hand pile volume and biomass is the size and shape of the fuel particles and how they pack together. “The magnitude of the difference in physical properties between hand piles and machine piles was surprising, as was the magnitude of the difference between conifer hand piles and shrub/hardwood hand piles,” said Wright.

Just as machine or hand pile composition varies considerably, so do the pile shapes and sizes. Depending on the specifications for each project or contract and the methods or equipment used to pile the fuels, there can be a difference between the shapes and sizes that result. Most hand piles have a circular or oval shape when viewed from above and a rounded shape when viewed from the side.

Among the 121 piles sampled, most were classified as either paraboloids or ellipsoids with a few half-cylinders, half-frustrums of a cone, and irregular solids.



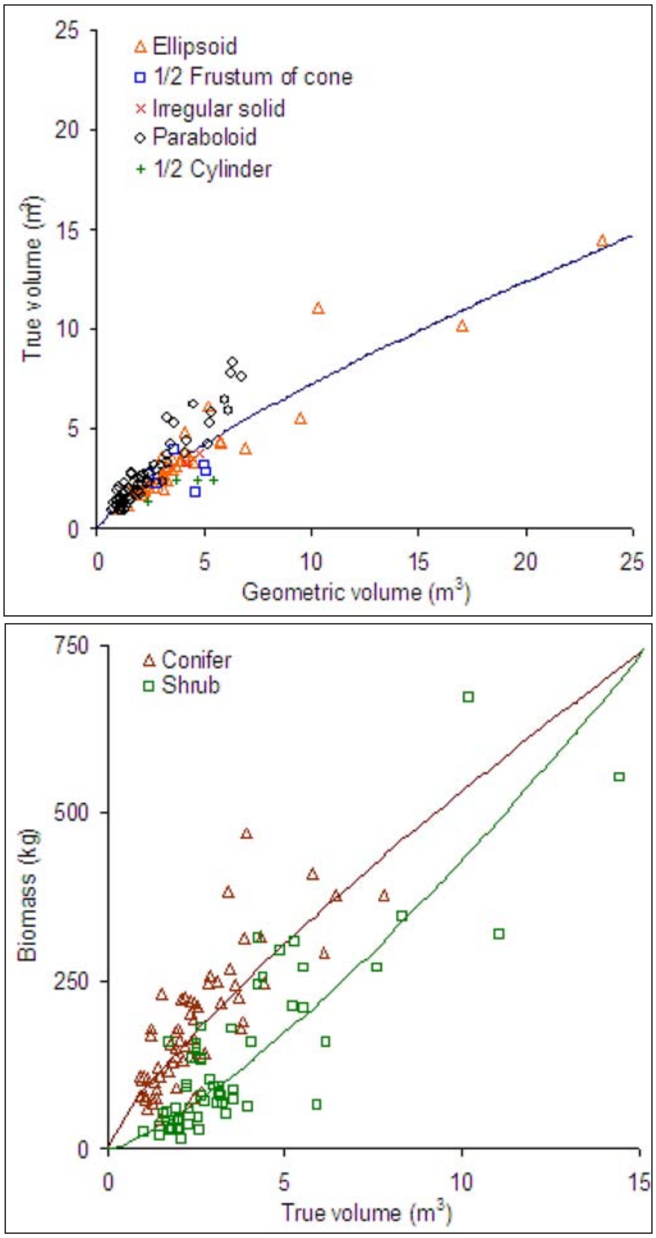
Geometric shapes and required dimensions to help characterize hand piles. Credit: Colin Hardy.

Calculating biomass and emissions with greater ease

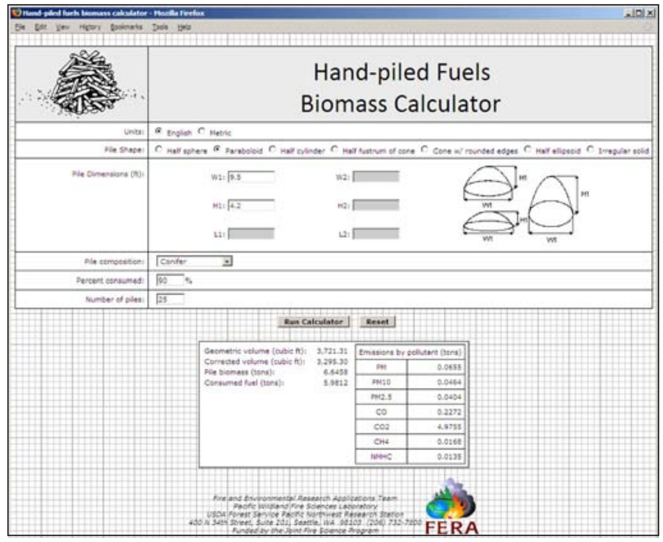
Since the Hardy/CONSUME method used data solely from machine-constructed piles, researchers recommend that fire and fuel managers use the online calculator located at http://depts.washington.edu/nwfire/handpiles to determine the volume, biomass and potential emissions of hand-constructed piles. To calculate results, users select a pile shape, enter the appropriate dimensions and number of piles, and indicate the composition (conifer or hardwood/shrub).

“This study allows managers to more accurately estimate the biomass of hand piles and therefore make better estimates of the air quality impacts when these piles are burned as a fuel and fire hazard management strategy,” said Wright. He added, “While the data used to develop the calculator are from western forests, the calculator should also work for other regions where conifer and shrub/hardwood debris is being piled by hand.”

Incorporation of the findings of this study into CONSUME has been postponed as the next generation of CONSUME is being re-developed and re-engineered. However, one advantage of the delay is that the researchers were able to develop a Web-based tool that managers can use to calculate hand pile characteristics without the need to install and develop expertise with specialized software.



Field measurements were used to determine the relationship between geometric and true pile volume (top) and true pile volume and biomass (bottom) for conifer and shrub piles of different sizes and shapes. Using geometric formulas tended to overestimate true volume, especially for larger piles. Piles of conifer debris showed a different relationship between volume and biomass than piles of hardwood/shrub debris; conifer-dominated piles typically weighed more for a comparable pile volume. Credit: Clint Wright.



Screen capture of the online calculator to help fuel and fire managers easily estimate hand pile biomass, volume, and potential emissions.

Careful calculations = More accurate results

Calculations and methods that work for machine piles may lead to inaccuracies when evaluating hand piles. For example, Hardy estimated pile and wood volume (that is, packing ratio) and applied values for wood density to estimate the weight of machine-constructed piles because they are larger in size and logistically difficult to weigh. However, since hand piles are relatively small, they can be weighed directly without specialized equipment. Therefore, rather than using Hardy's method of estimating pile and wood volume to derive biomass, the research team was able to develop a model that uses the direct weight of each hand pile. As a result, managers can more accurately estimate the biomass of hand piles without introducing an unknown level of error caused by trying to guess the appropriate packing ratio.

Errors can also occur when relating pile volume to pile biomass. Because no two piles are exactly alike, estimating the amount of solid material in a pile and determining packing ratio is challenging. Guidelines are available to help select the correct packing ratio by identifying particle size, general species and construction methods. However, these guidelines are only provided for machine-constructed piles. Further research would be needed to develop specific packing ratio guidelines for hand-constructed piles.

Initially, researchers thought that applying the estimation methods for machine-constructed piles to hand-constructed piles would over-predict biomass owing to hypothesized differences about how particle composition and packing might affect the relationship between pile volume and pile biomass. It turned out that shrub and hardwood hand piles were overestimated, but hand piles consisting of primarily coniferous material were actually underestimated. Guidelines in Hardy and CONSUME suggest the most appropriate packing ratio should be 0.10 for the material typically found in hand-constructed piles. Increasing the packing ratio from 0.10 to 0.15 for hand-constructed piles improved the accuracy of the biomass predictions for conifer-based piles, but worsened the biomass predictions for shrub and hardwood debris piles.

Using geometric formulas to determine pile volume can also create inaccuracies when assessing larger hand piles. This could have a significant impact on prescribed burning activities. For example, in Utah, piled debris up to 30,000 cubic feet is considered a small prescribed burn that requires no special permitting or approval as long as adequate smoke dispersion conditions exist. So, being able to correct this overestimation could help land managers treat more fuel within current guidelines and without crossing regulatory thresholds.

Striving for more: Next steps

Thanks to the work performed in this study and the previous research completed by Hardy, characterizing the biomass of piled fuels—whether created by man or machine—is no longer a mystery. There is a better understanding of the different variables that affect biomass such as pile volume and the size and species of fuel particles. There is also greater awareness of the factors that can skew biomass, and therefore emissions, estimates as well as what adjustments can be made to reduce errors. Most of all, fuel and land managers now have access to an online tool that can help them improve burn scheduling and smoke management and ensure compliance with air quality regulations.

Even with the successful completion of this study and the creation of the online calculator, additional investigation is needed to:

- Strengthen relationships between pile biomass and volume for larger hand piles.
- Develop relationships between pile biomass and volume for material types that were not sampled.
- Confirm the assumption that the emissions from burning hand piles and machine piles are the same.

Researchers would also like to expand the functionality of the online calculator by including the capabilities to estimate the weight, fuel consumption, and emissions of machine-constructed piles as in Hardy and CONSUME so that users will be able to use one tool to characterize piles of any type.

Management Implications

- Consider the method used to construct the pile before attempting to characterize biomass and potential emissions.
- Use the Hardy/CONSUME 3.0 approach to calculate biomass and emissions estimates for machine-constructed piles and the online hand pile fuels biomass calculator for hand-constructed piles.
- The online calculator will calculate the volume, biomass and emissions of one or more piles that are the same size and shape. Users should group piles into different size and shape classes if there is variability within the treated area to get the most accurate estimates.

Further Information: Publications and Web Resources

CONSUME Web site:
http://www.fs.fed.us/pnw/fera/products/consume.html

Hand-piled fuels biomass and emissions calculator:
http://depts.washington.edu/nwfire/handpiles

Machine pile biomass calculator: http://www.dnr.wa.gov/RecreationEducation/Topics/FireBurningRegulations/Pages/rp_burn_tonnagecalculator.htm

Hardy, C.C. 1996. Guidelines for estimating volume, biomass and smoke production for piled slash. Gen. Tech. Rep. PNW-GTR-364. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 17 p. http://www.treesearch.fs.fed.us/pubs/26244

Wright, C.S., C.S. Balog, and J.W. Kelly. 2010. Estimating volume, biomass, and potential emissions of hand-piled fuels. Gen. Tech. Rep. PNW-GTR-805. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 23 p.

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Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

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