FOREST BIOMASS PILES AND THEIR IMPACT ON WILDFIRE BEHAVIOR AND SEVERITY

LEAVING FOREST BIOMASS WASTE RESIDUE PILES IN THE FOREST INCREASES WILDFIRE SEVERITY AND SIZE

The impact of biomass piles on wildfire behavior and severity depends on various factors, including the structure and size of the piles, pile composition (which may include branches and limbs, trunks, bark, tree tops, and forest floor surface fuels), and their distribution across the landscape. When left behind from fuel reduction projects, they exacerbate fire behavior, create significant challenges for firefighting efforts, and can hinder post-fire forest recovery and long-term value.

Biomass piles significantly change how wildfires behave when they move through a landscape. These piles are concentrated fuel sources that intensify fire behavior when ignited[1]. When a wildfire encounters biomass piles, several things can happen. Piles can bridge surface and canopy fuels, increasing crowning potential[2] and creating wind channelization effects that accelerate surface winds. This combination enhances the risk of spot fires, as burning pile fragments lofted by convective columns create secondary ignitions. Small-diameter pile materials burn faster and hotter than that of large diameter logs, contributing to a greater number of spot fires. Forest biomass piles also have the potential to alter local microclimates by being drier than surrounding surface fuels due to lack of ground contact, which can promote erratic fire spread.

The presence of biomass piles is particularly concerning in the wildland-urban interface where forests meet human communities and extensive fuels mitigation work is needed or on-going. During the 2020 Hog Fire in California, significant quantities of dead fuel slash in clearcut units caused the fire to escape expected containment, resulting in firefighters losing control of the fire and ceasing ineffective air tanker support. Similarly, in the King Fire (2014) and Mosquito Fire (2022), residual logging slash piles contributed to increased flame lengths and presented significant challenges to suppression efforts, highlighting the dangers of leaving unmanaged biomass in fire-prone areas[3]. Partially treated units where slash piles were left behind often exhibit fire behavior similar to untreated stands with ladder fuels. Research on fires such as the 2007 Tin Cup Fire[4] and the 2006 Warm Fire has demonstrated thinning without subsequent treatment of slash increases burn severity.

The soil impacts of biomass piles during wildfires are also significant. High-intensity burns under these piles can sterilize the soil[5] and kill seed banks, creating persistent gaps in vegetation[6]. These gaps often become vulnerable to colonization by invasive species, altering the post-fire ecological recovery process. The long-term effects of these localized, intense burns can persist for years, influencing forest regeneration patterns and ecosystem composition.

It is often assumed that burning piles is the most cost effective way to dispose of this material. However, recent cost data on actual costs of pile burning by Barker et al. (2025[7]), and related potential impacts of smoke, show differently.

PRESCRIBED FIRE (BURNING OF BIOMASS PILES AND UNDERBURNS) HELPS REDUCE WILDFIRE SEVERITY AND SIZE

Pre-burned hand or machine piled slash (tops, limbs), brush (surface fuels), or small diameter trees (up to ~12” DBH), which are ignited individually or via controlled under-burns before a wildfire occurs, have shown the potential to reduce overall fire severity by acting as effective fuel breaks. This was observed during the 2002 Hayman Fire in Colorado, where pre-burned piles successfully halted fire spread in treated areas by eliminating surface fuels[8]. During the 2007 Tin Cup Fire in Montana[9], proactive slash management with burning helped contain the wildfire. For areas where slash had been removed, the intense crown fire transitioned to a less severe surface fire, preventing it from spreading further into the forest canopy.

By creating discontinuities in the fuel landscape, these managed (removed) piles can slow down fire progression and provide firefighters with strategic points for containment. Also, a Stanford-led study analyzing 20 years of wildfire data in California found that low-intensity prescribed burns reduced the risk of high-severity wildfires by 60% in mixed-conifer forests, with protective effects lasting at least six years. The research highlighted that treated areas retained 55% of live tree carbon post-fire, compared to 7% in untreated stands[10]. The Stanford report demonstrated prescribed fire’s dual role in carbon retention and wildfire mitigation.

OLD BIOMASS PILES ARE A LIABILITY AND SHOULD BE REMOVED

Biomass piles, including top and cull decks, are sometimes left for decades after various forest management operations. As forest management expands into wildland-urban interface areas, these piles are increasingly constructed near communities, raising logistical, fire hazard, and smoke impact concerns.

Biomass piles are classified based on several characteristics, including composition, compaction level, and construction method. Composition varies between conifer and shrub/hardwood species with different wood densities. Compaction levels range from 10% to 25%, depending on the materials and construction methods. Hand-built piles are generally smaller and less compacted compared to machine-constructed ones.

Coniferous material piles typically have higher bulk density due to larger woody particles. These characteristics influence how biomass piles behave during fires. The physical and chemical properties of biomass piles play a significant role in their combustion behavior[11]. The chemical composition of conifer and hardwood tree biomass includes lignin and carbohydrates, with variations by species. For instance, softwood contains more lignin than hardwoods. Key fuel characteristics include size, moisture content, arrangement, and fuel loading. Smaller fuels ignite quickly but burn faster, while larger fuels burn longer with higher intensity.

The aging process of biomass piles involves significant physical and chemical changes, creating distinct differences between new and old piles[12]. Over time, piles compact, losing about 15% of their height annually for the first two years. This increased density affects how fire penetrates and spreads through the pile. Foliage retention decreases as piles age, with most species losing foliage within the first year. Bark condition also changes, with disintegration becoming noticeable after a few years. Combustion characteristics differ as well; older piles typically produce shorter flames but burn for longer periods. They can also develop internal heat from decomposition processes, especially if they contain fine materials or soil. New piles, being less compacted and having higher energy content, may burn with higher peak flame heights but shorter durations.

MASTICATION AND CHIP AND SCATTERING CAN INCREASE WILDFIRE SEVERITY AND SIZE

Mastication and chipping, and then scattering of forest biomass generally results in lower wildfire severity compared to leaving standing biomass piles, with reduced flame heights, lower scorch impacts, better protecting the forest canopy during wildfire events and a smaller percentage of area burned during wildfires. Experimental studies have shown that chipped and scattered fuels limit fire spread, with only about half the area in chipped plots burning compared to untreated areas[13]. However, fuel treatment projects that do not remove surface fuels and leave that material in piles are not very effective at lowering fire risk, and may actually add to fire risk[14].

The accumulation of large amounts of wood chips on natural duff, sometimes has the ability to change potential fire behavior in concerning ways. Duff refers to a layer of partially decomposed organic material that accumulates on the forest floor. Duff can burn via smoldering combustion[15], which is a slow, low-intensity, flameless process that can persist for long periods and is challenging to detect. Smoldering can occur at duff moisture contents as high as 120–135%, although complete consumption of the duff layer typically occurs only when moisture content is below 30%. Particularly worrisome is the potential for prolonged heating during combustion. The smoldering of combined duff and wood chip layers can cause significant damage to trees through cambial injury and also has the potential for reignition. Mastication and chipping must therefore be applied thoughtfully and will not always achieve desired fire reduction with large accumulations of chips.

A SIDE NOTE: BIOMASS ENERGY AS ALTERNATIVE TO PILE BURNING AND ITS IMPROVED AIR QUALITY OUTCOMES

As mentioned above, pile burning, typically used if leaving piles in the forest is not ecologically sound, produces concentrated smoke emissions, posing air quality and public health concerns to neighboring communities. Removing the piled woody biomass waste and using it for energy production significantly reduces air pollutant emissions of particulate matter by 98%, nitrogen oxides by 54%, nonmethane volatile organics by 99%, carbon monoxide by 97%, and carbon dioxide equivalents by 17%[16]. Unfortunately, due to access to biomass waste piles (particularly on steep slopes, and no roads) and distance from the biomass source to the energy facility, the cost to chip and transport is frequently more than an energy facility can afford to pay for the biomass waste fuel. Mobile biomass units may offer a unique opportunity to process biomass in relatively close proximity to forest biomass piles and should be further explored.

CONCLUSION

Reducing fire risk is a top priority of California. In order to make sure our forest health and forest fuel management projects are successful, land managers, state policy makers and beneficial fire practitioners need to understand that piles, and even deep chip layers, can be a significant fire risk, not to mention aesthetically and ecologically unacceptable. As we face uncertain climatic shifts, these decisions are critical to successful wildfire management.

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[1] Pile burns as a proxy for high severity wildfire impacts on soil microbiomes." Geoderma, 2024, by J.A. Fowler et al.

[2] Post-harvest slash burning in coniferous forests in North America: A review of ecological impacts." Forest Ecology and Management, 2021, by Christine M. Mott, Richard W. Hofstetter, and Anita J. Antoninka

[3] FPC 4(a) Extant Slash Regulations." California Department of Forestry and Fire Protection (CAL FIRE), Board of Forestry and Fire Protection

[4] The influence of an incomplete fuels treatment on fire behavior and effects in the 2007 Tin Cup Fire, Bitterroot National Forest, Montana." International Journal of Wildland Fire, US Forest Service, Rocky Mountain Research Station, 2010, by Michael Harrington and Erin Noonan-Wright

[5] Effects of Pile Burning in the LTB on Soil and Water Quality." U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 2013

[6] Slash pile burning effects on soil biotic and chemical properties and plant establishment: Recommendations for amelioration." Restoration Ecology, 2004, by Julie E. Korb, Nancy C. Johnson, and W.W. Covington

[7] Assessing costs and constraints of forest residue disposal by pile burning." Frontiers in Forests and Global Change, 2025

[8] Hayman Fire Case Study." USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rep. RMRS-GTR-114, 2003, edited by Russell T. Graham

[9] Unplanned Wildfire in Areas with Slash Piles." Northern Rockies Fire Science Network, by Alexander M. Evans and Clinton S. Wright, 2023

[10] More smoke today for less smoke tomorrow? We need to better understand the public health benefits and costs of prescribed fire." International Journal of Wildland Fire, 2022, by Benjamin A. Jones et al.

[11] Estimating Volume, Biomass, and Potential Emissions of Hand-Piled Fuels." U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-805, 2010, by Clinton S. Wright, C.S. Balog, and J.W. Kelly

[12] Pile age and burn season influence fuel bed properties, combustion dynamics, fuel consumption, and charcoal formation when burning hand piles." Forest Ecology and Management, Vol. 439, pp. 146–158, 2019, by Clinton S. Wright, Alexander M. Evans, Sara Grove, and Karen A. Haubensak

[13] Fuels and fire behavior in chipped and unchipped plots: Implications for land management near the wildland/urban interface." Forest Ecology and Management, Vol. 236, pp. 18–29, 2006, by Jeff S. Glitzenstein, Donna R. Streng, Gary L. Achtemeier, Luke P. Naeher, and Dale D. Wade

[14] Tamm review: A meta-analysis of thinning, prescribed fire, and wildfire effects on subsequent wildfire severity in conifer dominated forests of the Western US." Forest Ecology and Management, Vol. 561, Article 121885, 2024, by Kimberley T. Davis, Jamie Peeler, Joseph Fargione, Ryan D. Haugo, Kerry L. Metlen, Marcos D. Robles, and Travis Woolley

[15] Post-fire Tree Mortality." U.S. Department of Agriculture, Forest Service, Research and Development, 2018, by Sarah M. Hood et al.

[16] Emission Reductions from Woody Biomass Waste for Energy as an Alternative to Open Burning." Journal of the Air & Waste Management Association, Vol. 61, pp. 63–68, 2011, by Bruce Springsteen, Tom Christofk, Steve Eubanks, Tad Mason, Chris Clavin, and Brett Storey