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Costs of Mechanical Fuel Reduction Treatments

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Synonyms

Biomass harvesting; Bush-hogging; Mastication; Mulching; Slash treatment

Definition

Mechanical fuel treatments are machine activities designed to change the size and arrangement of forest biomass by either severing stems and creating smaller fragments (mastication) or by removing these stems from the site (bundling, baling, biomass harvesting) for disposal or utilization. Cost of mechanical fuel reduction treatments is defined as the money spent in mechanical fuel reduction activities.

Introduction

Prescribed burning is used, particularly in the southeastern United States, to control understory vegetation. This practice can reduce the risk or severity of fire, but it can also provide benefits for wildlife habitat improvements and ecosystem health (Marshall et al. 2008). Prescribed burning is avoided in areas where smoke would create hazards for human health and transportation. It also cannot be used in areas that are so overgrown that a fire, once started, could burn out of control. In these instances, mechanical fuel reduction treatments are a viable alternative to either replace fire or prepare conditions for the reintroduction of prescribed fire.

Conditions that make it difficult to stop a fire may include stands with high stocking levels (many trees per hectare) and those with a large amount of overgrown understory and midstory vegetation (Agee and Skinner 2005). Stand characteristics that may contribute to increased fire risk are those that contain stems (trees and shrubs) that form a ladder of fuels from ground vegetation up into tree crowns. Wildfires can spread from tree crown to tree crown in stands with high stocking. These crowning fires are the most difficult to control. Therefore, controlling the midstory and understory vegetation is an important aspect of fuel management.

Fire risk can also be affected by the number of downed stems from natural disturbances, mortality, or the amount of logging residues. Mechanical fuel reduction treatments address fire risk by either removing vegetation or by breaking fuel connections by changing the size and arrangements of fuels.

A variety of mechanical fuel treatment options are available that may either harvest, densify,

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or masticate woody vegetation (such as timber harvests/timber sales, baling and bundling, and mastication) (Windell and Bradshaw 2000; Rummer 2010). Commercial timber harvests reduce fire risk by removing vegetation in the form of marketable forest products. Timber harvests may also include products that do not have an available market. These materials may be cut and piled to decay, burned, or used for firewood. Depending on the amount of unmarketable products, these timber harvests may result in income for the forest land owner. In other instances, land management objectives may result in timber harvests where no marketable products exist (noncommercial timber harvests) or where the cost of the operation exceeds the value or the products. Lastly, mastication is a treatment option that uses heavy equipment to change the size and arrangement of fuels with the objectives of either reducing the fire risk or severity. Mastication does not remove any material from the site and does not generate income for the land owner.

Timber Harvests

Timber harvests are an option where the costs of the fuel reduction operations can be offset by the value of the timber removed. Harvesting operations can aid in reducing the fire risk and severity in overstocked stands or break up the available fuel across a landscape. Foresters, or land managers, determine silvicultural/treatment objectives which, along with financial constraints, determine what kind of harvesting to perform (Gagnon 2015). Steps in timber harvesting would include felling, primary transport (forwarding, skidding or yarding), and processing (delimbing and bucking). Slash or residue left on site might be scattered, piled, or piled and burned. Slash, residue, or whole trees marketed as biomass products could be chipped, ground, baled, or bundled prior to transport.

Two of the most common silvicultural treatments employed in land management across all types of land ownerships are regeneration harvests and thinning (Gagnon 2015). Regeneration harvests are those where most, or all, of the standing timber is harvested and replaced over time by a younger stand through natural regeneration or planting. Thinning operations only remove selected stems to provide more site resources (e.g., sunlight, water, and nutrients) to the remaining trees. Each of these treatments can reduce continuous fuels by creating more space between tree crowns and reducing the overall crown density.

Regardless of the type of harvest, logging operations often leave behind tree tops, poor quality stems, branches, and other whole or partial stems that do not have a market value. This material is often called logging slash or logging residue. In fire-prone areas, logging slash can be a fire hazard. It can also interfere with natural stand regeneration or planting. There are two common treatments for logging slash, piling, and spreading. For piling, a bulldozer, often with a brush attachment, is used to push the slash into piles. These piles may be left in place, or they may be burned under safe conditions once the slash dries. Another option is to spread the slash so that it assists with erosion control. Once scattered, it will decay, returning nutrients and organic matter back to the soil.

Small diameter stems are typically stems that measure 12.7 cm (5 in or less) at a height of 1.4 m (4.5 ft) above the ground. These stems are typically not merchantable for traditional forest products (e.g., pulp chips or lumber). In some areas with available biomass markets, these small stems can be commercially harvested in the form of whole tree chips (bark intact). Producing whole tree chips may result in a profitable operation, or the biomass processing operation could be subsidized to meet land manager's objectives.

Baling and Bundling

Baling and bundling are processes that compress loose biomass into more manageable forms. Round or square bales or composite residue logs are used in areas where markets exist, such as in Sweden and Finland (Routa et al. 2013).

Costs of Mechanical Fuel Reduction Treatments, Fig. 1 Bales created from understory and midstory vegetation near Valdosta, Georgia, USA

Costs of Mechanical Fuel Reduction Treatments, Fig. 2 Bundler creating composite logs near Idaho City, Idaho, USA

When the fuel treatment is focused on shrubs and small trees, baling may be an option if biomass markets exist. Baling (Fig. 1) can be accomplished using a one-pass or a two-pass system. In a one type of one-pass system, a towed baler severs stems and processes them into round bales. These balers have been specifically designed to accommodate woody biomass. In a two-pass system, the stems are severed or masticated in the first pass and baled in the second pass. Transporting the bales to roadside may require another step. Further bale processing, such as grinding, would be needed for most biomass consuming facilities.

Bundling (Fig. 2) is another option that is used to densify understory and midstory vegetation or logging slash. Bundlers can pick up severed material or logging slash and compress it into composite residue logs. The cylindrical log shape is conducive to handling with traditional forestry equipment and can be cut to a variety of lengths from approximately 2.5 to 5 m (8.2 to 16.4 ft). Bundles differ from bales in not only their shape, but the material in the bundles must include longer pieces to provide the stiffness needed for handling. The bundle shape allows either chipping or grinding for further processing methods. Chipping, as opposed to grinding, provides additional benefits, such as better handling characteristics, for many systems.

An alternative to baling and bundling is a prototype one-pass system (Roise et al. 2009) with a modified horizontal shaft-cutting head. This prototype machine performed all actions (sever and chip) and collected the chipped material in a silage wagon. This system required a collection bin at roadside for dumping the wagon.

Mastication

Mastication can reduce fire risk, or severity, in overstocked stands by breaking the ground-to-crown vegetative connections (Kreye et al. 2014). Mechanical treatments break these connections by changing the size or arrangement of fuels without any removals. This type of operation is an alternative to prescribed burning when smoke management or other risks hinder its application and the primary focus is management of the midstory and understory vegetation. (For additional information the reader may see the contribution on masticated fuels.)

Equipment Selection

A variety of mastication equipment is commercially available. A cutting head is mounted on a variety of carriers, or prime movers, or towed. Prime movers may be large or small. They may be equipped with either tires or tracks. The choice of tires or tracks can depend on several variables including the steepness of the treatment area, sensitivity of the soils, or depth of organic matter. Generally, tires may cause rutting in areas with soft or wet soils. Compared to tires, tracks have a larger contact area with the ground, so they can distribute the weight of the machine across the tracks. In traditional forestry applications, wider tires or dual tires are used to reduce ground pressure, but for mastication treatments, the added width can inhibit navigation through a forest stand. On steeper terrain, machines with tracks are typically preferred.

Mastication cutting heads can be affixed/attached to prime movers or towed. Attachments can rotate cutting tools on a vertical shaft (like a mower) or a horizontal shaft. A variety of machine sizes, horsepower requirements, and tool widths are available.

Operational Characteristics

Managers must understand their desired conditions, or outcomes, when choosing both the type of mastication equipment and the operational parameters. These choices include decisions on resulting piece size, machine productivity, size of material to be treated, whether the material is standing or downed, machine trafficability, and other variables (Kreye et al. 2014). Management objectives, such as whether mastication is the first step toward reintroducing prescribed fire or is an alternative to fire in the wildland urban interface (WUI), will also affect treatment options.

Some types of mechanisms crush or shred the standing material, while others use more of a cutting type of action to masticate. Equipment choices can result in a variety of piece sizes left on the ground after treatment. However, the way that the machine is operated can also affect the piece size.

Operational characteristics can affect the outcome of mastication treatments. If the objective is to masticate small trees and shrubs quickly, a single pass with a machine may achieve the management objective. However, if this chunkier, scattered material does not meet the aesthetic requirements of the area (e.g., recreational area or WUI), a two-pass system may be required. Once the material is severed and masticated, a second machine pass with the cutting head operated closer to the ground can further reduce piece size. Equipment with fixed teeth work well in the two-pass system as flails and swinging hammers will have a tendency to swing back when they come into contact with the ground. In the second pass, teeth will dull quickly as they come into contact with the ground to resize the masticated material, resulting in a higher cost of treatment.

Over a landscape, treatment objectives can be met in a variety of methods. If the objective is to create a uniform treatment, the machine must treat every portion of a stand or landscape. To lower the cost of the treatment, a land manager may choose to identify low-risk areas or identify islands of vegetation to exclude from treatment. The objective to break up existing continuous fuels would still be achieved, but less area would be trafficked. Similarly, in dense stands, navigating between and around standing trees lowers machine productivity. Machine width and type of cutting head can address tight maneuvering, or alternatively, the operation could leave dense pockets of standing trees untreated.

Special conditions can arise that require special machines or higher costs for treatments. Larger standing trees can be efficiently treated with boom-mounted machines (Fig. 3) equipped with fixed tooth horizontal shaft-cutting mechanisms. This type of equipment can reach up to clip the top out of a tree and then masticate

Costs of Mechanical Fuel Reduction Treatments, Fig. 3 Boom-mounted mastication machine processing midstory vegetation in a wildland urban interface near Havelock, North Carolina, USA the standing portion of the tree vertically until it reaches the stump. The head can then process the clipped top on the ground. While this method reduces productivity, it may be necessary to meet a management objective, especially in sensitive WUI areas. Masticating large downed trees can also significantly reduce production.

Costs

Operational costs typically include four components: overhead, labor, fixed, and variable (Miyata 1980; Rummer 2008). Overhead refers to the support costs of the business (e.g., transportation, professional services, communication, parts inventory, etc.). Labor costs include the wage or salary of the machine operators and direct support personnel on the crew and indirect labor costs (e.g., employee benefits, taxes, and workers compensation insurance). Fixed costs are related to machine ownership and capital expenses including the capital recovery (depreciation), capital costs (interest), and risk management (insurance). Variable costs include items consumed as the machines operate such as fuel, lubricants, and tires, plus a budget for the expected replacement and repair of parts subject to wear and failure, such as knives and hydraulic hoses. The principal factors in operational costs of a specific system are the productivity (units per hour) and the system utilization or percent of time the system is available for work. Factors that reduce system utilization are generally classified as delays. Operational delays include time in transport between locations, interference or bottlenecks from machine interactions, supervisory or planning activities, and disruptions due to weather. Mechanical delays include time lost for both scheduled and unscheduled maintenance on machines. There is an inverse relationship between system utilization and cost. Utilization rates rarely exceed 80% for mobile forestry equipment (Miyata 1980).

Commercial timber harvests are the least costly operations reviewed because they generate income. Comparing the cost of the three generalized types of timber harvests (regeneration harvests, thinning, and small diameter harvesting), the main factors in harvesting costs are volume per tree, volume removed per area, and haul distance. Contrasting the three harvest types, regeneration harvests typically include larger trees and remove more volume per area than either of the other types of timber harvests (Baker et al. 2010). For thinnings, the economics can vary because they can be performed at various intensities and tree sizes which will impact the volume to be removed (Bolding et al. 2009). Small diameter harvesting is the most costly because it takes more time and generates little commercial volume.

In cases where there is a market for biomass from small diameter biomass, producing whole tree chips or other nontraditional forest products should be less expensive than mastication because value is generated from the product removals. Mitchell and Gallagher (2007) found that fuel treatment with whole tree chipping cost 25% of the projected mastication cost. Biomass production costs are sensitive to volume per hectare, stand type, and scale of operation (Enrich et al. 2010). On average, 7 tons/ha (20 tons/ac) was considered the minimum requirement for an economic biomass harvest.

Baling productivity ranged from 2.0 to 6.0 green tons/hr. (2.2 to 6.7 green ton/hr) (Canto et al. 2011). They found that the two-pass system was twice as fast as the one-pass system. However, overall, the cost per ton was similar between the two systems due to the capital investment for the additional machines needed for the two-pass system.

Bundling productivity can be influenced by logging slash arrangement and stand density. Longer unmerchantable stems and high slash densities enhance bundling productivity. Rummer et al. (2004) predicted production rates up to 8 bdt/hr. (bone dry tons/hour). Bundling operations, at most, removed approximately 50% of the slash. Cost and production comparisons between bundling and baling are difficult because they are used in completely different applications, respectively, logging slash and standing understory and midstory.

When considering the cost of mastication treatments, both the cost of the machine and the production rate must be addressed (Halbrook et al. 2006). A smaller machine with a lower initial cost may not provide the lowest-cost treatment if it takes more time to treat an area. Advantages of smaller machines are that they can be transported easily, do not require oversize hauling permits, and can be hauled on a variety of flatbeds or trailers. Operational characteristics, such as one-pass or two-pass, will affect treatment costs. One of the interesting dilemmas of mulching treatments is whether to compare treatment costs on the basis of treatment area or by hourly production.

Terrain and stand factors can impact treatment costs. Mastication treatment on slopes above 35% can reduce machine productivity (hectares/hour) by approximately 10–20% (Halbrook et al. 2006), thus increasing the cost of the operation. The presence of downed logs, larger than 15.2 cm (6 in) in diameter, can easily double the cost of mastication treatments when using a boom-mounted system (Dodson 2016). Tree density (number of standing trees per hectare) can also significantly impact productivity and costs.

Summary

All of the tools summarized are needed to address the variety of conditions under which fuel treatments are applied. When commercial biomass markets are available, whole tree chipping and small diameter thinning operations, as well as baling and bundling, may become feasible. Integrated contracts are those which provide for timber harvesting and also include fuel treatment services. These types of contracts are one way to leverage the value of commercial forest products to help offset the cost of fuel treatments. The most important factor in fuel treatment costs is the operational objectives rather than the equipment. For a manager, an initial step would be to determine the range of acceptable results, which may exclude or favor some treatment types. Budget limitations (costs) and timber harvest options (potential income) provide further decision criteria for managers.

Cross-References

▶ Canopy Fuel
▶ Fuel Continuity
▶ Fuel Moisture
▶ Fuels Characterization Techniques
▶ Ground Fuels
▶ Ladder Fuels
▶ Masticated Fuels
▶ Natural Fuels
▶ Prescribed Burning
▶ Surface Fuel
▶ Surface to Crown Transition
▶ Wildland Fuel Dynamics
▶ Wildland Fuel Treatments

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