TECHNOLOGY FOR TREATING FUELS AND SMALL-DIAMETER MATERIAL

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Abstract

Many forests have become overstocked with small-diameter material. Treating these stands to address forest health or fire hazard concerns is costly because of the requirement to physically handle many pieces with little offsetting product value. Efforts to find solutions have intensified with recent wildfire and insect outbreaks. New technological developments have focused on either reducing the material in the stand (mastication) or concentrating the material into more efficiently handled bundles (biomass bundling). Production studies of various types of mastication equipment found rates from 0.1 ha/hour to as much as 1 ha/hour. Key variables affecting rate include type of machine, slope, residual spacing, and degree of fuel treatment specified. Biomass bundling equipment developed in Scandinavia was tested in North American conditions. The productivity of the machine was significantly affected by steep slopes, residual stand spacing, and down fuel loading. Production ranged from 6.5 bundles per hour to over 10 bundles per hour. Biomass recovery can be economical, particularly if the avoided cost of alternative fuel treatments is considered.

Keywords: biomass, costs, fire, thinning

Introduction

In recent years, wildfire and forest health problems in the western U.S. have focused attention on overstocked forests. Resulting primarily from the exclusion of wildfire, excess stocking produces higher fuel loadings, more severe fire behavior, species composition shifts, increased competitive stress, reduced tree vigor, and increased susceptibility to insects and disease. Schmidt et al. (2002) delineated the extent of the problem by overlaying vegetation type, fire interval, and climatic variables to estimate *condition class*, a measure of how far forests may be from natural fire-dominated conditions. Over 11 million hectares in the western US could be classified in Condition Class 3 (mechanical treatments necessary to restore forest condition). An additional 16 million hectares would be considered Condition Class 2 (moderate treatment necessary to restore condition). Using broad inventory data and a general thinning prescription, Vissage and Miles (2003) estimated that thinning just the Condition Class 3 stands would require treatment of 576 million bone dry tons. This scale of treatment would be nearly 10 times the total annual commercial harvest in the region (Rummer et al., 2003).

The challenge of dealing with these overstocked stands is exacerbated by factors including: lack of markets for biomass, long transport distances, restrictions on the use of fire, realistic constraints on available funding, and the expanding wildland-urban interface. Forest managers need appropriate forest operations that can deal with millions of small stems and significant volumes of biomass within these limitations. Two new technologies that have evolved are biomass treatment in the stand with mastication, and biomass recovery and extraction with biomass bundling. This report describes recent studies of these operations, their applications and limitations.

Fuel Treatment Prescriptions and Operational Constraints

Forest operations are tools to create conditions specified by prescription. In order to affect potential fire behavior, fuel reduction prescriptions must modify specific fuel strata. Raising crown base height, for example, can reduce the potential for crown fire initiation. Graham et al. (1999) describe the fire behavior effects of a range of prescriptions for western US forests. Their review concludes that treatments must be carefully designed to reduce wildfire risk. Thinning treatments may even intensify fire behavior if activity fuels increase surface loading. In general, a fire prescription must address both surface fuel conditions and canopy characteristics. Surface fuels may be the most critical element, however, since crown fire behavior is generally initiated and driven by surface fire conditions.

While there are several approaches to treating critical surface fuels, a key constraining factor is economics. Cutting, handling and transporting large numbers of small volume pieces is costly. Every additional operation adds expense. Where markets do not exist for biomass products (a common problem in many areas of the western US) there is a strong incentive to treat the material as close to the stump as possible. Prescribed fire treatments are one of the most cost-effective options for reducing surface fuels. Cleaves et al. (2000) found that prescribed fire costs ranged widely by Forest Service region, from $150/ha to $844/hectacre (1994 US$, western regions only). While forest managers felt burning was effective and intended to increase the amount of burning treatments, barriers to increased burning were identified. Issues like smoke management, risk of escape, limited burning "windows", shortage of skilled personnel, and environmental regulations limit the application of prescribed fire treatments. In some cases these issues may exclude burning as a treatment and mechanical alternatives must be used to accomplish fuel reduction objectives. In other applications, mechanical treatments offer the potential to recover product value that can partially offset treatment costs. Mastication is a mechanical treatment that can be used in lieu of fire to reduce fuels in the stand. Biomass bundling is an alternative that allows recovery of forest residues for potential utilization.

Mastication

Mastication equipment reduces biomass in the stand by shredding, chipping, or grinding standing and downed material. Masticated material can take many forms from small chips to stringy material to large chunks depending on machine type and operating method. The immediate effects are increased crown base height, reduced crown bulk density (depending on the extent of midstory reduction), increased surface fuel bulk density, reduced surface fuel depth, and increased surface fuel loading. The resulting stand condition may be acceptable for the re-introduction of broadcast burning or it may be left as a complete treatment without the need for burning. There are questions about re-sprouting, long-term stand response to mastication, nutrient cycling effects, and fire behavior impacts. However, mastication is widely used and appears to meet many resource manager's objectives.

There is a wide range of equipment configurations on the market (Windell and Bradshaw 2000). The cutting heads are broadly classified as either horizontal shaft or vertical shaft, referring to the axis of cutter rotation. Some cutting units have teeth that are rigidly attached while others use swinging, flail-type bits. Each of the types of cutting heads can be mounted on a variety of prime mover base machines, including steel-tracked tractors, rubber-tired articulated tractors (Fig. 1), skid-steer loaders, or swing machines (i.e., excavator or feller-buncher conversions). The possible machine configurations range from less than $100,000 (US) to over $400,000 (US).

A number of production studies were conducted to better evaluate performance characteristics of mastication machines. Mitchell and Rummer (1999) compared productivity of a swing-mounted horizontal drum cutter with a rubber-tired horizontal drum cutter across a range of residual stand spacing. The rubber-tired machine was faster than the swing machine and was able to operate in tighter residual stands. The maximum production rate, basically limited by travel speed, was 0.6 ha/productive machine hour (PMH) for the wheeled machine and 0.3 ha/PMH for the tracked machine.

A second study on the Kisatchie National Forest in Louisiana compared the performance of a low-ground pressure tracked machine to a rubber-tired machine. Both machines carried the same type of horizontal-shaft cutter head. In the relatively open pine stands of the study area, the fuel reduction treatment focused on reduction of understory hardwoods and excess pine regeneration. Production of the rubber-tired

Fig. 1 Rubber-tired mastication machine

machine averaged 0.5 ha/PMH while the low-pressure tracked machine averaged 0.3 ha/PMH. Visual assessment of soil disturbance showed no significant difference between the two machines.

A third study at Ft. Benning, Georgia evaluated the productivity of high-horsepower mastication equipment (~370 kW). Two horizontal shaft masticators, one a rubber-tired machine with flail hammer teeth, the second a tracked machine with rigidly mounted teeth, were tested. The primary difference between the two machines was the basic trafficability afforded by the prime mover. The rubber-tired machine was unable to treat all of the area due to soft soils and some steep terrain. The tracked machine was able to operate on the more difficult terrain. Both machines were able to average 0.4 ha/PMH on flat plots. Production was reduced by half when operating on steep slopes or broken terrain.

The production studies have found that, in general, rubber-tired carriers have the highest productivity and swing-mounted cutters are the slowest. Vertical shaft mastication machines tend to have lower costs and higher production than horizontal shaft machines. However, horizontal shaft machines can usually treat larger fuels. With the range of possible fuel outcomes and associated costs, it is important for managers to understand the differences among equipment alternatives.

Biomass Bundling

In some areas with heavy surface fuel loadings, simply grinding the material in place will not be sufficient fuel reduction. If there are nearby markets for biomass, an alternative fuel treatment is biomass bundling. This technology is used in Scandinavia to collect forest residues for heat and power generation. Basically a biomass bundler is like a hay baler—it picks up forest residues, compacts them, and wraps them up with baling twine. Several manufacturers offer machines that produce bundles approximately 3 m long and 0.5 m in diameter. One study refers to these as composite residue logs (Andersson et al. 2000). A key characteristic of the bundles is that they are similar in shape and weight to short logs. This facilitates handling with conventional log loading and transportation equipment.

During the summer of 2003, a Timberjack 1490D bundler (Fig 2) was tested on seven different forests in the western US. The sites represented different forest types, different terrain, and different thinning treatments. Biomass bundles of green residue had an average density of about 320 kg/m^3.

Fig. 2. Biomass bundler operating in Idaho

Productivity ranged from 5 to 24 bundles/PMH. Production was primarily impacted by the arrangement and loading of residues. The operator spent most of his time collecting and loading scattered material in order to keep the bundling mechanism occupied. Where residues were concentrated, productivity increased. Analysis of time study data indicated that a production rate of 26 bundles/PMH should be realized with 50 tons/ha (Rummer et al, 2004).

Although biomass recovery can help offset the costs of treatment, the value of forest residues for energy production are currently not sufficient to fully cover bundling, extracting, hauling and chipping. A breakeven comparison suggests that if alternative fuel treatments exceed about $15/bone dry ton, biomass bundling and recovery could be economically viable.

Summary

The operational requirements of treating small-diameter materials and forest fuels are complex and highly variable. There is no single forest operation that can deal effectively with all the possible site-specific situations that arise. Therefore a range of tools must be developed, supported and available to resource managers. It is important in assessing the economics of mechanical treatments to consider the avoided costs of alternative fuel reduction strategies. Biomass product value will not be sufficient to offset total operational costs.

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