Forest Fuel Reduction Through Energy Wood Production Using a Small Chipper/CTL Harvesting System

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ABSTRACT – In the summer of 2000, fire destroyed millions of acres of forest across the United States. This study investigates the feasibility of harvesting to reduce forest fuel buildup and produce energy wood. Cut-to-length (CTL) harvesting coupled with a small in-woods chipper provides a low impact way to harvest pre-commercial trees and tops along with merchantable logs. While CTL harvesting systems have been used successfully with full sized chippers, it requires two or three CTL teams. A smaller, less expensive, chipper which is expected to have similar productivity to a single harvester – forwarder team and have reasonable ownership and operating costs, will allow operations to stay small and efficient. A CTL/small chipper system is projected to be an efficient way of reducing forest fuel loads and less expensive than fire suppression and stand-replacement costs after wildfire. Energy wood from fuel reduction harvesting could be used as an alternative energy source. The benefits of energy wood become more important as fuel prices increase. The feasibility study suggests that if energy equivalent values were obtained, a CTL/small chipper system could provide income rather than expense for site conversion, cleanup operations.

INTRODUCTION

Most forest industry professionals agree that smaller trees will be the wood and fiber source of the future. With increased intensive forest management practices, trees are growing faster and producing value more quickly. This forces industry and land managers to look into new and more innovative ways of harvesting small trees. Fire control and exclusion have led to an increase in the non-commercial midstory and understory components of forested stands (Mitchell and Rummer 1999). Most of the national forests, as well as other federal, state, and private landowners, have problems of overstocked and stagnated stands of trees. Typically, these stands have very large numbers of stems per acre and their growth has stagnated before the trees have reached a size that would contain marketable material by conventional standards. Besides being a utilization problem, these stands are very vulnerable to fire or insect attack because of the stressed nature of the trees. Conversion of these stands, removing the existing trees and re-establishing more appropriate species, is also cost prohibitive because of the lack of efficient harvesting methods for this material (Karsky 1992).

In densely overpopulated stands, which have developed without stocking controls, small trees can cause fire hazards by high levels of fuel loads. Small trees tightly spaced in the understory of mature forests create a fire ladder increasing the risk of a possible stand destroying fire. Small trees, limbs, and tops, without current merchantable value, are potential targets for in-woods chipping operations. Some advantages of an in-woods chipping system include the ability to recover fiber from limbs, tops, and un-merchantable wood, high productivity, and advanced site preparation (Stokes 1988). Current in-woods chipping operations also have the disadvantage of requiring large tracts of timber for successful operations due to the high cost of moving and setting up large, expensive chipping machines from tract to tract.

SYSTEM BACKGROUND

Cut-to-Length (CTL) harvesting systems have proven to efficiently harvest a variety of tree sizes including first commercial thinnings. Studies have shown CTL to be a low impact form of harvesting. It provides minimal residual stand and site damage and requires less manpower and leaves fewer slash piles than traditional tree-length systems (Lanford and Stokes 1995).

Many CTL harvesting systems offer state-of-the-art equipment and the best available technology to maximize timber utilization, and protect water quality and other natural resources at the same time. In CTL operations, the two-machine system, a harvester and a forwarder, balance to give an efficient operation for smaller tracts. The harvester provides the felling, limbing, and bucking functions. Harvesters can be mounted on excavator carriers using tracks or purpose-built carriers with bogie rubber tires with tracks, which reduces soil compaction especially when a bed of limbs is placed in the tread way. Many harvesters fell and process trees with an attachment mounted on a boom, therefore using a swing-to-tree motion for felling, as opposed to the drive-to-tree method used by most feller-bunchers. The harvester reaches many trees from a single location without moving, which reduces the amount of travel throughout a stand. Less travel means less soil compaction and damage to residual trees.
The second machine in a CTL system is a forwarder. This machine can have four, six, or eight tires and appears

similar to a skidder with a loader and trailer attached. Instead of using a traditional skidder, which drags wood on the ground, a forwarder carries wood clear of the ground. Due to large payloads, a forwarder can haul wood economically for long distances and needs only minimum skid trails and landings. Less soil is displaced, rutted, and compacted. The onboard loader can place logs for stream crossings and easily remove them when the crossing is no longer needed. The short length of a forwarder and wood package translates into less stand damage (Hartsough, Drews, McNeel, Durston, and Stokes 1997, Lanford and Stokes 1995).

This system varies from the typical southern tree-length system because the trees are limbed and bucked into lengths at the stump, leaving limbs and tops evenly distributed throughout the tract (Stokes 1988). With social and aesthetic concerns becoming increasingly important, CTL operations stand to become the system of choice.

CTL systems with only a single harvester and forwarder do not match well with traditional in-woods chippers. Traditional chippers are very costly and require two to three CTL teams to provide an adequate supply of wood. Since it would be highly desirable to combine the advantages of this low impact system with in-woods chipping, a possible solution would be to use CTL with a smaller chipper.

A smaller, less expensive chipper might have reasonable ownership and operating costs and allow operations to stay small and efficient. A CTL/small chipper system could also prove to be an efficient way of reducing forest fuel loads. Recent wildfires in the Western US have destroyed millions of dollars of valuable timber and property. Public demand for wildfire protection is growing. Recent drought years, tree species composition changes, and declining forest health within fire dependent ecosystems have exposed a large number of communities to a potential for stand-replacement fires. For many reasons, including fire suppression, forests that were once relatively open have become dense with trees and understory brush. Fire exclusion has allowed trees to fill stands that were once characterized by widely spaced fire resistant trees. Large wildfires can have major ecological impacts on soils, fish, wildlife, water resources, timber resources, recreation uses, air quality, visual quality, archeological sites, homes, developed structures, electronic sites, and human life. Wildland fuels have been accumulating over the past fifty years due to wildland fire management policies, wildland management practices, and other factors. As a result, the number and size of large, intense fires have grown over the last decade, resulting in higher fire suppression and preparedness costs and greater damage.

The suppression and stand-replacement costs from these fires are expected to be higher than many fuel reduction methods. Fuel reduction is not an easy operation to execute. Traditionally, forest fuels have been reduced by prescribed fire, but prescribed fire is unpopular due to increased liability concerns and state and federal regulations associated with smoke management.

The use of commercial thinning in dense stands for fuel reduction can also be difficult and expensive within the current merchantability standards. Thinning of a stand for fuel reduction with most stems being of non-merchantable size is expensive for conventional tree-length and CTL systems due to low production, and therefore, high costs of wood produced.

PROPOSED SOLUTION

Use of a CTL/Small Chipper operation may be a possible solution. This system may be able to reduce forest fuel loads by reducing the number of trees per acre and removing slash produced during the harvesting operation. In overstocked, even-aged stands and multi-storied stands alike, reduction in the number of trees per acre will open the forest canopy releasing the better trees to grow in value. With this approach, previously non-merchantable stems will become merchantable.

For trees with only energy value, it is anticipated that harvesters will be more productive by only felling without processing. Forwarders will carry entire trees off the ground in full tree form (stem, top, and limbs) along with limbs and tops from merchantable trees, therefore leaving minimal slash for future fire hazards. The larger payload of forwarding is preferred over ground skidding to keep the material free of dirt, which provides longer life for chipper knives.

Even if the smaller chipper cannot provide chip quality acceptable for pulp due to bark content, chips will be useable for energy wood. With fuel prices at an all time high, energy wood from this type operation could prove very marketable. Since CTL operations excel in the merchandising of small sawlogs, even from overstocked stands, the combined value of chips and merchandised products might be very profitable. Also, landowners may be willing to accept a reduced stumpage payment if they get the "cleanup" of this type of operation.

The use of wood as a fuel source works extremely well in the forested U.S., especially in areas where alternative sources are scarce. Only a small fraction of the total amount of wood biomass available for fuel is actually used to produce energy. Because of technical, economic, and social reasons, the utilization of wood fuel has been slow to gain wider acceptance (Stokes 1989). Fuel chips are fairly homogeneous which makes the product work well with existing handling systems from storage to the furnace. In eastern Canada, fuel chip burning installations are typically found in schools, hospitals, greenhouses, factories, etc

(Stokes 1989). In the U.S., fuel chips can be used to fire kilns at lumber mills and digesters at pulp mills. They also have municipal purposes such as mulch for landscaping and organic matter for flower gardens. With technology increasing daily, uses for wood fiber, as an alternative energy source, are expected to expand.

A metric green tonne of chipped slash at 45 percent moisture content has an energy content of approximately 8750 mJ and, assuming a 65 percent energy conversion efficiency, it will produce 5687 net mJ in a furnace. In comparison, a barrel of bunker "C" oil contains 6508 mJ and, assuming 85 percent energy conversion efficiency, will yield 5532 net mJ. A metric green tonne of chipped slash is therefore roughly equivalent to one barrel of bunker "C" oil (Stokes 1989).

With rising gas and oil prices, and the positive effects of producing energy from a renewable natural resource coupled with reducing forest fuel buildups for fire prevention, the CTL/small chipper approach seems to have promise for the future.

CONCEPT FEASIBILITY

In order to better understand the cost relationships of in-woods chipping with CTL harvesting, a target stand of trees was identified from forest inventory records (USFS 2001) (Table 1) and harvested using the Auburn Harvesting Analyzer methodology (Tufts et al 1985). A review of current efforts to reduce fire hazards has not identified a "typical" stand, but it is expected that this stand will probably represent a high fire hazard situation. The harvesting of this stand will represent a conversion from a high fire risk to a cleared area ready for planting. Since all material will be harvested, the site will need little or no additional site preparation before planting. It is recognized that other fire hazard reduction scenarios exist such as thinning of young overstocked even aged stands and removal of understory with some merchantable overstory removal.

The stand in Table 1 would be considered half stocked or less with merchantable trees, most of which are of saw timber quality. Total tons are expressed as the green weight of the total tree (wood, bark, and foliage) above the stump. Merchantable tons are expressed as the green weight of the stem (wood and bark) to a 4-inch top (not including limbs, tops, or foliage). The merchantable portion of the stand will be merchandized into products and delivered to a mill for maximum revenue. Non-merchantable tons are defined as the difference between total tons and merchantable tons. This is the portion of the stand including limbs, tops, and foliage from diameters of 5 inches or greater and total trees with diameters less than 5 inches. It is assumed that all non-merchantable material will be chipped for energy wood.

Approximately 27 percent of the total above ground biomass is currently considered non-merchantable.

Table 1. Typical Natural Southern Pine Stand in the Southeastern United States with a Dense Non-merchantable Understory

DBH	Trees per Acre[1]	Total Height[1]	Total Tons per Acre[2]	Merchantable Tons per Acre[2]	Non-Merchantable Tons per Acre[2]
1	78.38	10	0.10	0.00	0.10
2	62.96	15	0.43	0.00	0.43
3	57.94	15	0.82	0.00	0.82
4	43.06	25	1.65	0.00	1.65
5	12.08	30	0.82	0.71	0.11
6	9.87	40	1.29	1.10	0.18
7	8.08	45	1.63	1.38	0.25
8	6.64	55	2.14	1.80	0.34
9	5.93	55	2.45	2.04	0.42
10	4.01	65	2.42	2.00	0.42
12	3.63	70	3.45	2.81	0.65
14	2.94	75	4.13	3.31	0.82
16	2.06	80	4.08	3.23	0.85
18	1.16	80	2.95	2.31	0.65
20	0.93	80	2.96	2.29	0.68
TOTAL	299.67		31.33	22.97	8.36

[1] USFS National Forest Inventory and Analysis Database Retrieval System
[2] Clark and Saucier 1990

Cost and productivity estimates of CTL harvesting were based on a study by Lanford et al (In review). The small in-woods chipper costs and productivity were projected from personal conversations and chipper manufacturer literature. Costs and productivity were estimated for cutting the total stand and chipping the non-merchantable portion. Costs from this calculation were compared to costs of harvesting only the merchantable portion. The difference of these costs would be the incremental increase in cost caused by harvesting the non-merchantable portion.

During harvesting, non-merchantable trees will be felled and piled along with limbs and tops from merchantable trees. Merchantable portions will be processed into log lengths and piled separately. The forwarder will transport the non-merchantable material to a chipper and merchantable log lengths to setout trailers. The forwarder will feed the non-merchantable portion, with its onboard loader, directly into the chipper, which will blow the energy chips into a van.

Cost assumptions, as shown in Table 2, represent a compilation of user and manufacturer recommendations for CTL systems and small chippers.

Projected harvesting costs for a forty-acre tract with a stand as shown in Table 1 using a CTL/small chipper system are shown in Table 3. To balance the harvester and forwarder productivity, the forwarder was operated for two shifts with different operators. While tonnage increased by 36 percent when all biomass was harvested, the average DBH declined by 50 percent. Harvesting of merchantable and non-merchantable components increased onboard costs by 61 percent as compared to harvesting only the merchantable portion.

Table 2. Cost Assumptions for a CTL/Small Chipper System

Machines	Harvester	Forwarder	Chipper
Initial Cost ($)	422,000	267,000	60,000
Expected Life (yrs)	6	6	5
Fuel and Lubrication ($/PMH)	7.03	6.42	9.26
Repair ($/PMH)	10.79	5.06	171.43
Labor ($/SMH)	12.50	25.00[1]	0.00

[1] Labor cost is for two forwarder operators; each working one shift per day to balance the system.

The difference in cost between harvesting only the merchantable portion of the stand and harvesting the merchantable and non-merchantable portions will be equal to the cost of harvesting non-merchantable material. For the stand in Table 1 harvesting costs will be $334.20 per acre for the non-merchantable material. This translates into a $39.98 per ton cost.

Table 3. CTL/Small Chipper Cost Projections

Harvested Portion		Merchantable Portion Only	Total Above Stump Biomass
Average DBH (inches)		9.09	4.58
Tons / Acre		22.97	31.33
$ / Ton	Fell and Process	2.96	4.27
	Forward	2.74	3.53
	Chip	0	2.40
	Support	2.07	2.35
	Total (Onboard Truck)	7.77	12.54
	Haul (75 miles)	14.33	14.33
	Total (Cut-and-Haul)	22.10	26.87
Total $ / Acre		507.64	841.84
Delivered cost of energy wood		**$334.20 / Acre** **$39.98 / Ton**	

Dubois et al (2001) reported the following per acre stand regeneration costs: shearing, raking, and piling - $144.53; chemical site preparation - $95.05; burning - $22.13. While chemical treatments were not added during the CTL/small chipper harvest, the tract will benefit equivalent to having it sheared, raked, piled, and burned for a total savings of $166.66 per acre.

In addition, the material removed as chips can be converted to energy. Based on Stoke's (1989) conversion to crude oil, a metric green tonne of chipped slash roughly has an energy content equivalent to one barrel of crude oil. (One imperical ton equals 1.0160 metric tons.) At current oil prices of $25.59 per barrel for crude (Nymex, April 2001), energy wood is worth $26.00 per ton. For the stand in Table 1, this equates to an income of $217.36 per acre.

Combining harvesting costs with site preparation savings and income from energy wood sales gives a net saving and income of $49.82 per acre. Assuming that this net income could be realized, a complete site preparation would only cost $45.23 per acre if a chemical treatment were included.

Another approach might compare the CTL/small chipper application to manual pre-commercial thinning. Dubois (2001) reports pre-commercial thinning costs to be $82.67 per acre. Taking the energy income from the harvesting cost leaves a cost of $116.84 per acre. While more expensive than pre-commercial thinning, the resulting stand would have the non-merchantable material still on the ground that might be a fire hazard. If the harvesting treatment can be counted for site preparation, the added saving ($166.66 per acre) would again put the CTL/small chipper approach as an income producer rather than a cost center.

CONCLUSIONS

The proposed harvesting system not only harvests material economically, but also provides energy wood, a product to be sold for monetary gain. The CTL/small chipper system also utilizes the non-merchantable portion of merchantable size trees, which in the past has normally been wasted. The gain from the value of energy wood and merchandized logs makes this system attractive in monetary terms, not to mention the fuel reduction gains received.

Based on this brief feasibility examination, there appears to be an opportunity to reduce fire hazards and create income from energy wood using a CTL/small chipper harvesting system. There are a number of questions that will be answered during field studies such as 1) productivity of the harvester felling very small trees, 2) productivity of the forwarder transporting and feeding the chipper with the non-merchantable material, 3) productivity and costs for the small chipper, and 4) amount of non-merchantable material that can be recovered with this approach.

For this report, only a stand conversion scenario was explored. Partial cuts in young and mature stands need to be examined. Also, $26 per ton energy wood value exceeds current market rates. Only after field verifications of costs would industry seriously consider a large-scale use of energy wood. Although it is felt that with proper utilization this value can be realized.

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